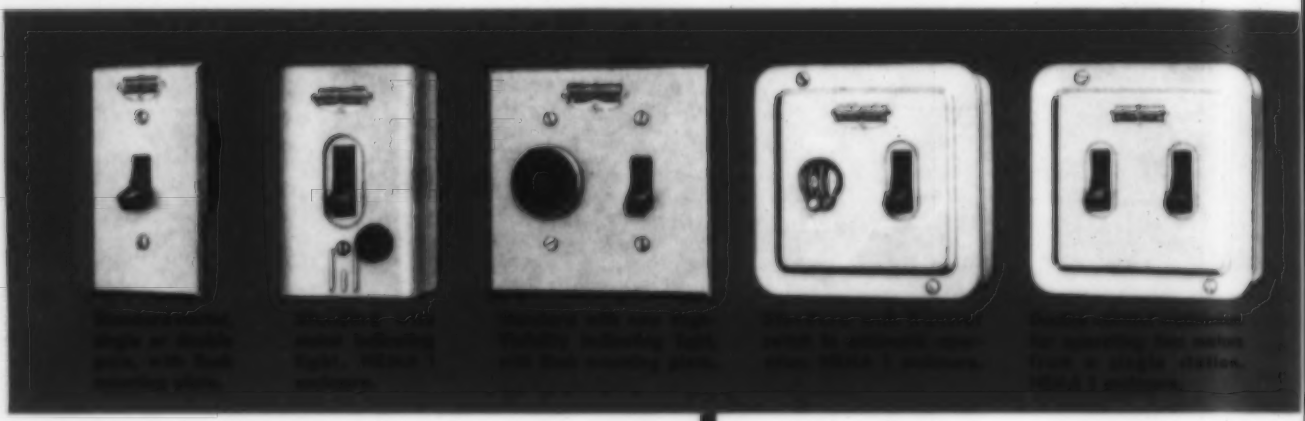
ENTON PU
DRIVE and

Now-the 9101 "Family"

The Cutler-Hammer Line of fractional horsepower manual starters now includes new mechanisms, new styling, new uses



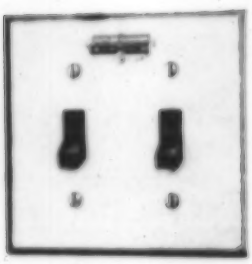
In order to meet the ever-growing needs of the market with a starter of proven design, Cutler-Hammer now brings out a complete family of Bulletin 9101 Manual Starters for fractional horsepower motors.

This family now includes the standard starter with motor-running indicating light, with standard or with high-visibility lenses. It now includes a standard switch together with transfer switch to automatic operation with padlocking provision. It now includes a "2 in one" model, two starters in one case for controlling 2 motors from a single station.

Another feature of great interest is the optional brushed stainless steel flush plate for installations such as hospitals, modern office buildings, etc. Conventional finish is gray baked enamel on a bonderized undercoat.

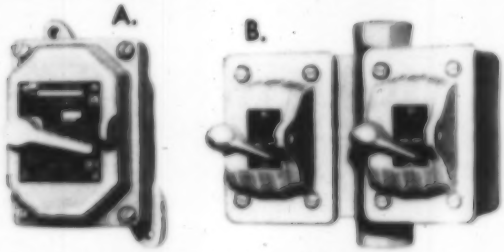
9101 starters are available for mounting in a standard Gem or Handy outlet box; for flush mounting; for surface mounting. The 9101 is a high-quality line at no premium cost. Its features include single or double pole, quick make and break silver contacts; eutectic alloy overload protection; straight-through wiring; wrap around covers, etc., etc. Available at your authorized Cutler-Hammer distributor. CUTLER-HAMMER, Inc., 1310 St. Paul Ave., Milwaukee 1, Wis. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ont.

Open type, mounting in Gem or Handy outlet box.



Skeleton starter with flush-mounting plate.

Enclosed surface mounting construction.



A. Starter in NEMA 7 or 9 Special Service Enclosures.

B. Duplex starter in NEMA 4 or 5 Special Service Enclosure.

CUTLER-HAMMER
MOTOR CONTROL
C-H

THE PROFESSIONAL JOURNAL FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

OCTOBER 1955
Volume 27—No. 10

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Over the Board

What the Editor Wants

Several MD editors belong to a group known as the Society of Business Magazine Editors. (As a matter of fact, editor Colin Carmichael is on the executive committee.) This is probably the reason why a small booklet recently published by SBME attracted our attention. Called *What the Editor Wants*, the booklet is primarily a guide for people preparing business or technical news releases. It also contains a list of the publication members of SBME and their editors. We have a few extras, so we'll be happy to send a copy to anyone interested.

Saum Tael!

As deadline dates approached this month, the editor in charge of this page was deeply immersed in scanning a weird and wonderful collection of exotic foreign conversion units contained in a book called *Conversion Factors and Tables*. Such things as 1 *man* (Iraq) equals 0.05 *hogga*.

Missing a deadline is an unpardonable editorial sin. So when the boss walked in, here's what happened, in *Conversion Factors* vocabulary:

"Shaku (Japan) leg," the *bozze* (Libya) says. "You're *ketting* (Indonesia) us in a *picul* (Philippines). Step up the *powa* (India)! *Gat* (Ethiopia) this *sho* (Japan) on the *roede* (France)!"

"Oka (Cyprus), *bozze,"* I *pipe* (Malaya) up, "don't *fuss* (Austria). I *kan* (Finland) *duim* (Netherlands) now."

With that, I *pic* (Greece) up my *bundle* (Union of S. Africa) of editorial *fodder* (Denmark). Right on top is this book, *Conversion Factors and Tables*.

"Saum (Switzerland) *tael* (Indonesia)," I think, "I *bat* (Indochina) this would be *pfund* (Germany). I'll take a *staab* (Switzerland) at it."

"Baa (Saudi Arabia)," says the *bozze* when he sees it. "And we *paimoneh* (Iran) for this *punkt* (Austria) stuff."

I agree, but *once* (Tunisia) you *reed* (Israel) this *Conversion Factors* book, you *chest* (Indonesia) *kend* (Ethiopia) *stop* (Sweden).

This Month's Cover

Just one year ago this month, MACHINE DESIGN started a program of articles on major types of adjustable-speed drives. First article in the group was on electric-motor units (October, 1954). Next came two major articles on mechanical types (April and June, 1955) which were followed by a report on magnetic slip couplings (July). This month, Keith Carlson's article on hydraulic adjustable-speed drives, Page 214, rounds out the program. Cover by George Farnsworth depicts the familiar JIC symbol for a hydraulic motor, and a four-way valve for reversing.

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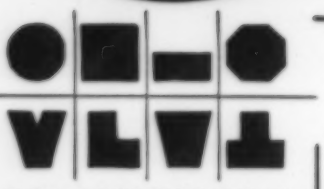
EATON RELIANCE

BETTER, FASTER

Reliance Spring Lock Washers, available in all types, sizes and analyses, keep bolted assemblies *tighter longer.* For complete lock washer information, write for Engineering Bulletin W-50.

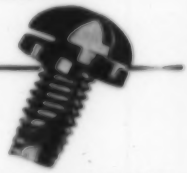
Eaton Standard Springtites and Sems speed production by combining spring washer and bolt or screw into one easily handled part. Engineering Bulletin S-49 has all the details.



Reliance Cold Finished Steel is available in rounds, squares, flats or special shape sections in wire sizes 020 x 020 x ½ to 9/16 in coils or cut to length. Write direct for information on sizes, shapes and analyses.

Reliance Hoz-Fas-Ners save time and money wherever rubber, plastic or fabric hoses are used. Rust resistant, re-usable, one piece design . . . maintain uniform automatic tension. Write for Engineering Bulletin No. 1.

Reliance Snap Rings save man hours and material on shaft assemblies, bearing applications and in counterbore assemblies. Shoulders quickly formed by machining a groove and snapping in a Reliance ring. Send for Bulletin 4K/3.



Eaton Thread-Cutting Springtites and Sems eliminate tapping when fabricating products. They cut their own threads as they fasten assuring perfectly mated, tightly seated threads. Full information in Engineering Bulletin S-49A.

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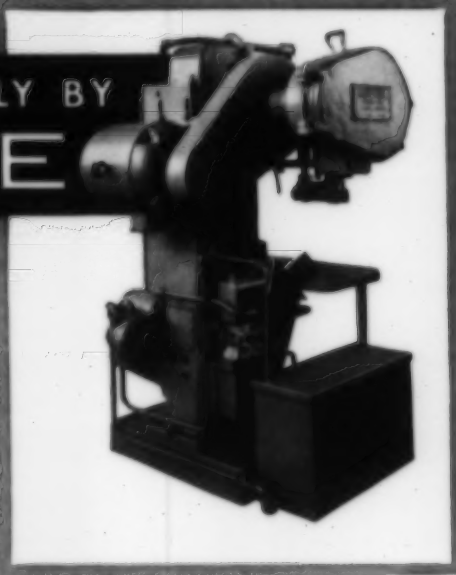
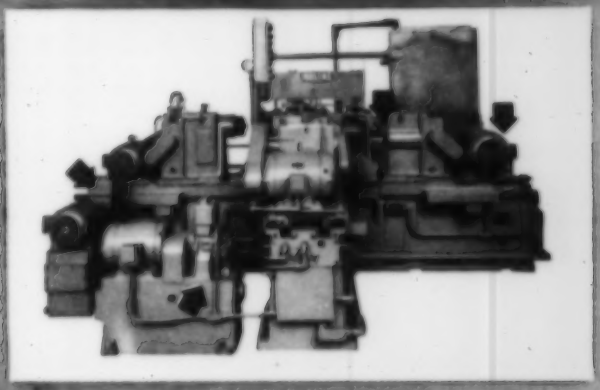
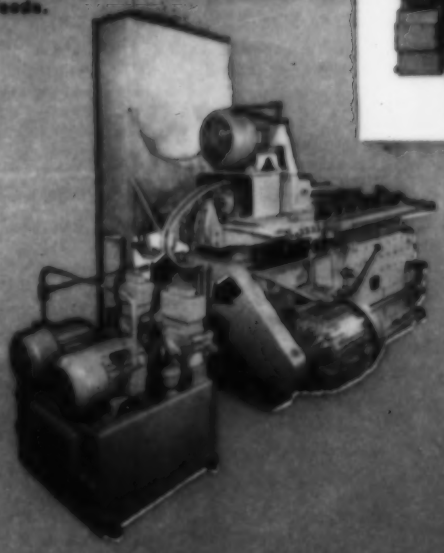


Above, Moline Drilling Machine employing "JK" Feed Pump.



Moline 4-way horizontal boring machine uses 4 Oilgear "JK" Feed Pumps.

Below, Moline special 38-spindle back-spotfacing machine using 2 "JK" units for vertical and horizontal feeds.



Below, Moline ten-foot, straight-line drilling machine using "JK" Feed Pump.

The Moline Tool Company, long established and respected in industry, has used Oilgear Fluid Power Feeds since 1925. Of Oilgear "JK" Fluid Power Feed Pumps used in its machines, Moline says these pumps *combine* the advantages found only in part in various mechanical feeds. Also, the "JK" Feed Pump provides infinitely, steplessly variable speeds; you can easily find the speed best suited to the work or condition of tools. Traverse speed can be as much as 365 times the feed rate. Coarse and fine feed rates are variable over a 30 : 1 range. Cycle time is cut drastically, production increased, costs reduced. Feed rates are maintained accurately despite varying work pressures by a built-in automatic pressure compensator.

"JK" Feed Pumps are simple, compact, electro-hydraulically controlled units, easily installed nearby or remotely. Systems need only a pump with reservoir, a double-acting cylinder, standard control and two easily connected pipes. Eliminating expensive engineering, these units can simplify design, reduce manufacturing cost, improve performance and increase salability of machines. Manual, semi-automatic or full automatic operation. Available now in 4 sizes. Write for free literature.

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FACTS

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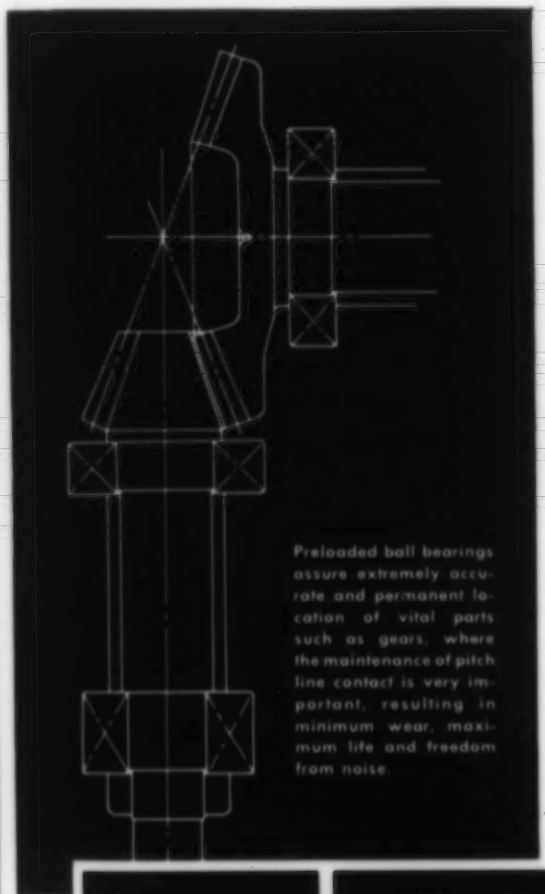
NEW DEPARTURE
BALL BEARINGS



Preloaded ball bearings assure extremely accurate and permanent location of vital parts such as gears, where the maintenance of pitch line contact is very important, resulting in minimum wear, maximum life and freedom from noise.

How Preloading Pays Off in Accuracy!

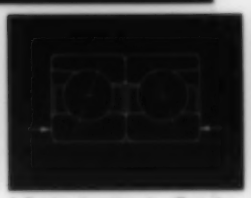
New Departure pioneered preloading to give you a new measure of machine accuracy! This accuracy, due to increased bearing rigidity, pays off in high-precision machines, where the slightest deflection caused by work loads on moving parts can be crucial to the ultimate performance of the machine.

By placing a predetermined internal load on the bearing, either at the time of manufacture or at installation, deflection due to the work load is greatly reduced. This means not only that machine accuracy is greatly improved, but that the ball bearing characteristics of low torque operation and long life are fully retained.

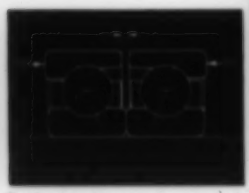
If you are seeking a solution to your bearing problem, call on New Departure for the answer. You will benefit from more than 50 years' experience in bearing design, testing and manufacture.

Send for Booklet BA-1 on ball bearing application

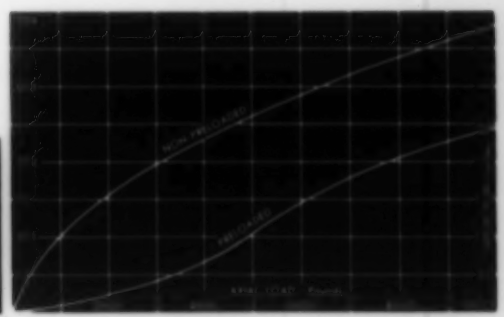
Preload is predetermined, then accurately obtained by grinding Duplex bearing faces so that an exact and fixed compression will take place when mounted.



A Duplex bearing, in effect, becomes a preloaded double-row bearing capable of holding parts within close limits, both radially and axially.



Duplex bearings may be mounted in several different ways to suit load conditions. In each case, extra rigidity of shaft centering is obtained by preloading.

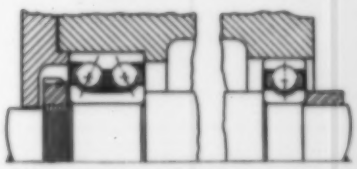


The benefits of preloading can be seen from this deflection curve. The double-row ball bearing referred to here is the most rigid type of unit bearing made to resist loads from any direction.

Typical Application of New Departure Preloaded Ball Bearings

The extreme resistance to deflection and the freedom from wear offered by the New Departure double-row bearing make it a favorite wherever exact location of parts under combined loads must be assured not only initially, but throughout long usage.

In this typical application the double row, solidly supported against suitable housing and shaft shoulders and with a "floated" single row at the other end, provides one of the best general-duty mountings where considerable thrust is present.



NEW DEPARTURE • • DIVISION OF GENERAL MOTORS • BRISTOL, CONN.

Engineering News Roundup

Engineer's Salaries Increase Over 1954

Survey Shows Most Engineers Got Pay Raises Last Year

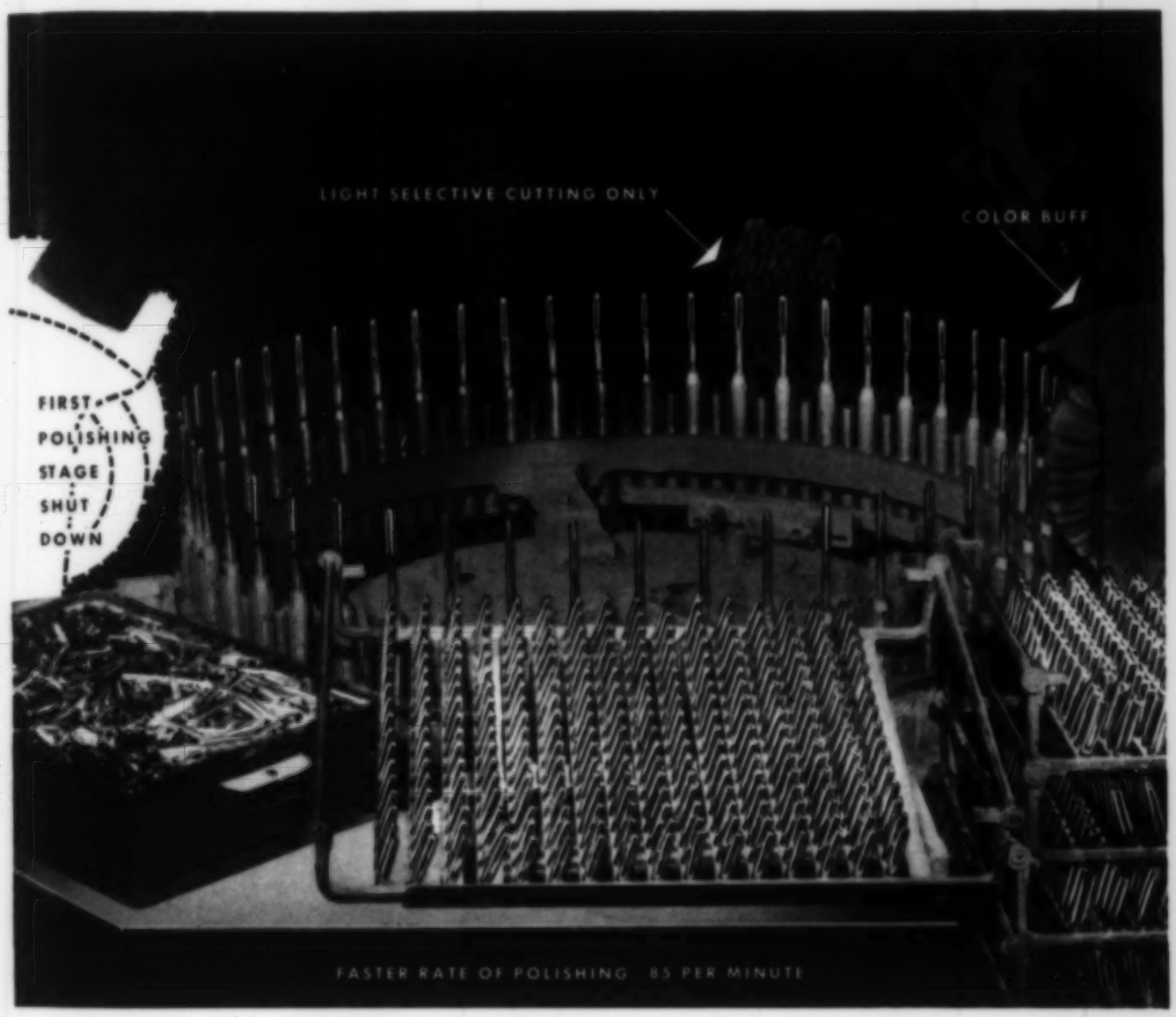
NEW YORK, N. Y.—Engineers' salaries have increased about 4.5 per cent in the past year, according to a recent survey. Most of the companies surveyed by the Executive Compensation Service of the American Management Association reported they granted increases to individuals in engineering and other professional groups during that period.

About 21,000 individuals in 20 engineering and professional job categories in 19 industries were covered. In all cases, the jobs are exempt from compulsory overtime penalty pay provisions of the Fair Labor Standards Act. Most of the positions studied are technical or highly specialized in nature. Typical job titles are project engineer (electrical or mechanical), industrial engineer and sales engineer.

Range of salaries reported was surprisingly narrow, according to the AMA report. An average beginning engineer receives about $4500 a year. Median pay for industrial engineering positions is about $6000 a year. Chemical positions pay about $6500 annually while median pay for electrical and mechanical engineers is $7000.

Pay level for these 20 administrative and technical positions is about the same as production foremen. Geographical location seems to make no difference. Salaries do not vary considerably among industries or with company size. This is in contrast to top manage-

EMERGENCY POWER is provided by this mobile plant designed and built by Caterpillar Tractor Co. Installed on a 32-ft long trailer, the diesel-electric plant is rated at 315 kw max. The unit is capable of operating over 10 hr on one tankload of fuel oil and may be refueled without stopping the engine. A Caterpillar D397 engine rated at 500 hp drives the generator



How Formbrite cuts polishing costs 40% for JARCO

Pens, pencils, and lipstick cases have to be attractive to sell—yet they must be able to take a beating in daily use. The Jarco Metal Products Co., which specializes in drawing metal parts for these and such other products as miniature flashlight cases, and similarly formed products, tried Formbrite,® Anaconda's new drawing brass, shortly after it was announced to the trade.

Superior polishing characteristics combined with excellent drawing properties, plus hardness and scratch resistance, sounded ideal for Jarco products. Formbrite has proved an excellent pressroom material. The uniformity of temper from batch to batch eliminated shutdowns for adjustments in their battery of 12-plunger Waterbury-Farrel presses, which can produce up to 500,000 pieces a day.

It's in the polishing room where Formbrite has really paid off. Jarco uses 50- and 98-spindle continuous-loop machines having two cutting stages and a final color buff stage. The first cutting stage is shut down completely. The second stage is used for only a partial or selective cut in certain areas of the cap—because of the extremely deep draw. The color buff stage does most of the work. The savings in polishing run about 40%, according to David Roberts, vice president.

Formbrite is a premium product at a nonpremium price. Find out for yourself how its superfine grain, excellent drawing properties, strength, and scratch resistance can help you make a better product at lower cost. Write for Publication B-39. Better yet, ask about a sample or a trial batch. Write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

Formbrite

FINE-GRAIN DRAWING BRASS

an ANACONDA® product

made by

The American Brass Company

ment positions, in which salaries are higher in larger companies.

Bonuses are scarce among technical and professional employees. Foremen and "middle management" personnel receive more bonuses than engineers. Only a fifth of the individuals included in the survey received bonuses last year, while two-fifths of the production foremen received bonuses.

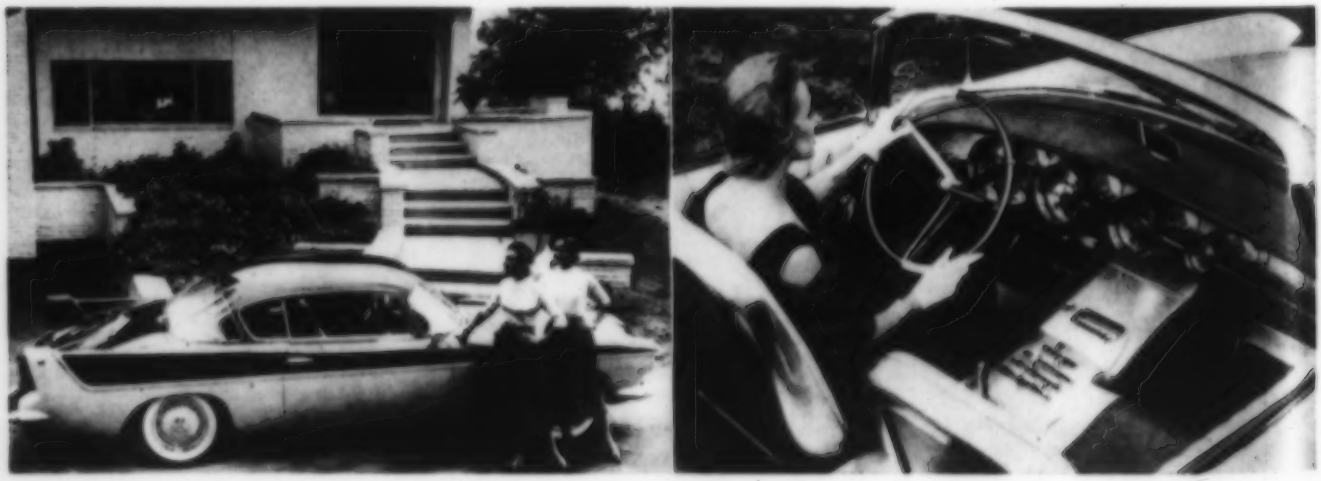
Proposed American Drafting Standards Manual, Section 9 — Forgings, is being distributed by the American Society of Mechanical Engineers. This tentative draft is being distributed for criticism and comment and is subject to revision. Interested parties may obtain copies of the draft free of charge by writing Mr. Frank Philippbar, Standards Dept., American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y.

U. S. Industrial Designers To Go Abroad

NEW YORK, N. Y.—American techniques of designing to increase sales will be brought directly to craftsmen in a number of non-industrialized countries, under a new program announced by the International Co-operation Administration.

Five U. S. industrial design firms have signed contracts with ICA to provide technical assistance in product design and marketing in such widely separated countries as Vietnam, India, Korea and Egypt. Purpose of the project, according to the Society of Industrial Designers, will be to assist these countries in discovering new fields in which native skills can be applied profitably. American industrial designers will work with craftsmen in redesigning their

IDEA CARS: These three Chrysler cars have been designed to test public acceptance of new styling concepts. Flight Sweep I, upper left, seats four passengers. It has a wheelbase of 120 inches, overall length of 207 inches, and overall height of 53½ inches. Flight Sweep II, lower left, is identical mechanically. Both models are styled with a sharply sloping windshield and upswept rear fenders. A console, lower right, is placed between the seats for heater, turn-signal, and automatic-transmission controls. A third model, Falcon I, upper right, is a two-passenger sports roadster. Its wheelbase is 105 inches, with an overall length of 182 inches and overall height of 51 inches. Its externally-mounted exhaust system is said to provide a powerful "mechanical" look. Engine horsepower of the three models was not disclosed by Chrysler. Although none of these models are for sale, some of the ideas may be employed in future production models



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CANADA, RAILWAY & POWER ENGR. CORP., LTD.

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products to take advantage of these opportunities and advise as to tools and methods which will increase output. Counsel on finance, export and marketing methods is also included in the project.

Experimental Machine Eliminates Hand Wiring

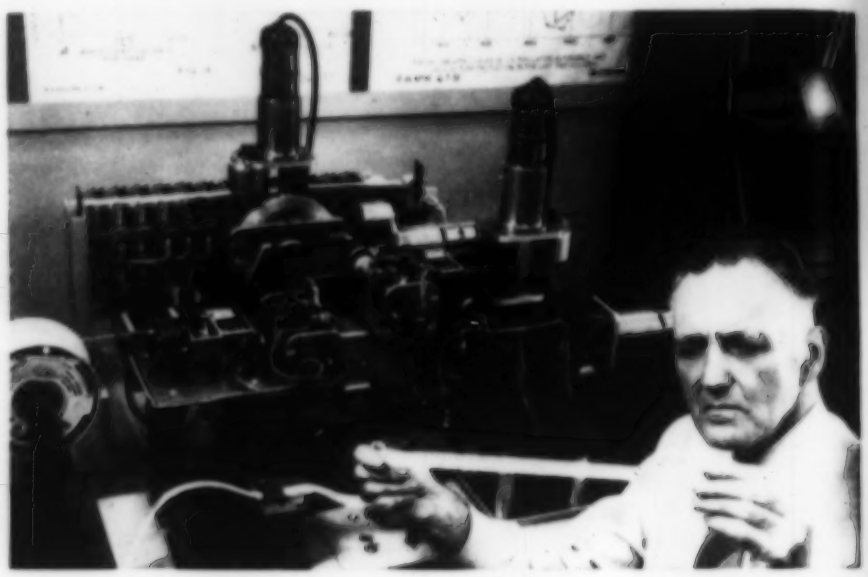
Electrical Units Wired Faster by Automatic Machine

NEW YORK, N. Y.—Automatic wiring of complex electrical assemblies is accomplished with a newly developed experimental machine. Called the M-4, the device was developed by Bell Telephone Laboratories.

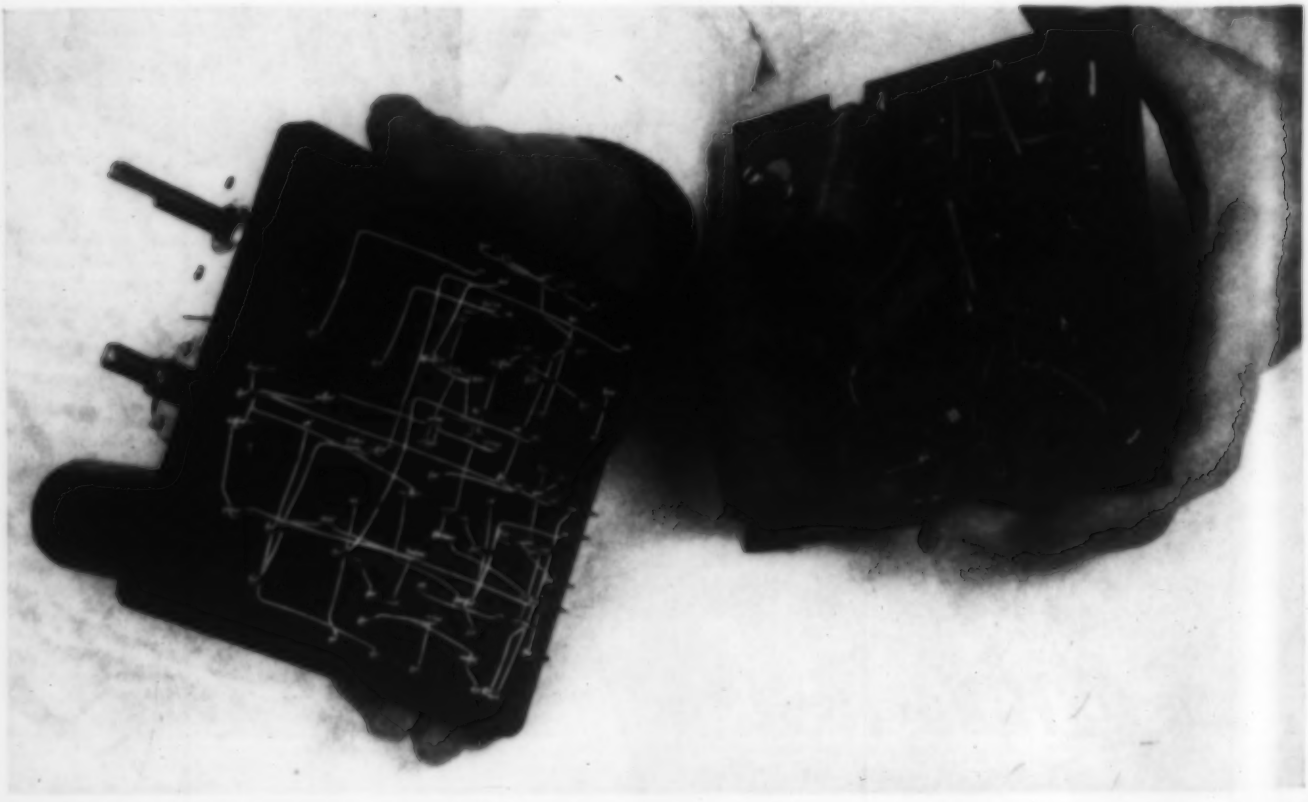
Instructions are fed to the machine from a punched tape. A series of relays transform the taped information into electrical signals. These signals in turn control the cams and gears of the machine.

Wire is fed from a large spool to one of two rotating spindles. The wire is pulled, in an inverted L-shaped movement, to a connecting terminal. At the same time, the wire is cut to the correct length at the second spindle. Insulation is removed from the ends of the wire as the spindles wrap it around the connecting terminals.

Solderless connections are made



Complex electronic and electrical equipment can be wired by this experimental machine developed by Bell Telephone Laboratories. Instructions are contained on the punched tape. Relays in the background are energized by the tape and in turn control the operating mechanism of the machine



Two five-tube radio receivers wired by different methods are shown here. Ordinary soldering methods were used to wire the one on the right. Bell Lab's automatic wiring machine wired the one on the left

Point of Honor

From the collection of Lewis Winant, New Jersey Arms Collectors Club. Maker: Johann Kuchenreuter, Regensburg, Germany, 1740-1757. An 11-by-14 inch print of this illustration with bearings and lettering omitted is available on request on company letterhead.

In today's business dealings (as in yesterday's "affairs of honor") both parties are protected by an intangible factor known as INTEGRITY—a figurative handsake between producer and consumer. Today, this point of honor assures you that the product you buy is exactly as represented. When you write COMPO Oil-Retaining Porous Bronze Bearings into your specifications you find that it is a point of honor with Bound Brook, as a reliable manufacturer, to provide you with the best powder metallurgy bearings that can be produced.

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by wrapping the wire six times around the terminal, producing a pressure of about 15,000 psi. An airtight, corrosion-resistant contact is thus provided between the wire and the terminal.

After one connection is completed, the spindles pick up more wire and move to the next two terminals, according to the punched-tape instructions.

According to Bell Labs, the M-4 may be set up to wire a series of similar panels on which may be mounted electron tubes or other components. Several machines of the M-4 type may be used at once, all controlled from one master tape.

Supercharger Uses Plastic Rotor Vanes

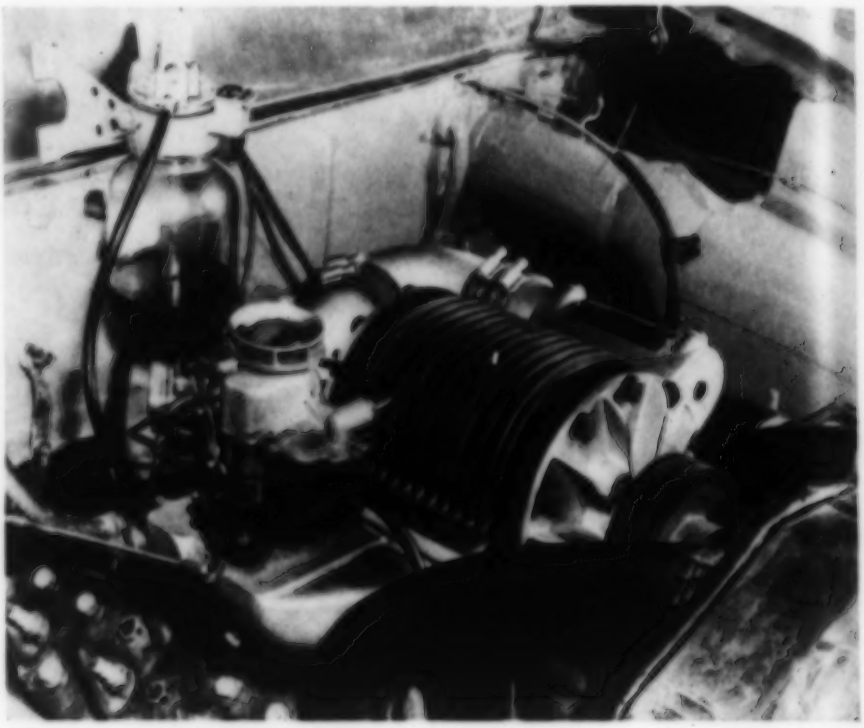
Laminated Plastics Make Light, Efficient Rotor

CONSHOHOCKEN, PA. — Thermosetting laminated plastic is now being used for supercharger rotor vanes. Designed for passenger autos by Judson Research and Mfg. Co., the supercharger features a rotor of high mechanical strength and long life.

A positive-displacement rotary-vane unit, the supercharger improves engine performance and permits faster acceleration. About 40 per cent more horsepower is added.

Chemical resistance and dimensional stability are both features of the plastic rotor vanes. Since the vanes are relatively light, the starting inertia is low. Good dimensional stability of the plastic laminate, made by Synthane Corp., assures a fixed volume of air at all engine speeds over a temperature range from below zero to 200 F.

One model of the unit has been designed for 1950-1955 Fords and Mercurys. A second fits a number of GM models. No alterations are required on either the engine or body.



Plastic-vane Judson supercharger is shown mounted on a passenger-car engine

TILTABLE TRAILER developed by the Corps of Engineers' Research and Development Laboratories features a tilting bed with rollers to facilitate launching this bridge section. The rollers are locked to prevent rotation in transit. They can also be retracted to provide a flat bed. Need for a crane at a proposed bridge site is eliminated when using this method of launching

Exhibitors Move in as...

Machine Tool Manufacturers Show New Machines

New Machines Feature More Automatic Controls

CHICAGO, ILL.—More automatic operation with greater accuracy seemed to be the principal feature of the new machines shown at the recent Machine Tool Show here.

Lathes, grinders, shapers, milling machines, presses and their accessories made up the bulk of the exhibits. Equally important, however, are the many gaging devices enabling high-accuracy measurements. New machines employing ultrasonics, as well as many new special-purpose machines, made their initial appearance.

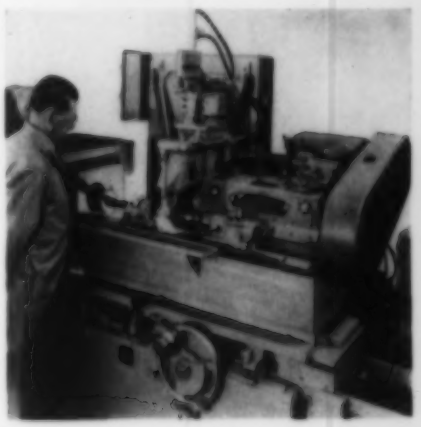
This trend toward automatic control is shown by highlighting some of the exhibited machine tools. Many measuring devices accessory to the tools themselves have been made adaptable to an automatic control system.

Automatic Cam Grinder: High-volume production grinding of automotive type camshafts at reduced costs is provided automatically with this new grinder. Made by Norton Co., the machine features precision at high speeds with simplicity of operation.

Operation cycle is completely automatic. Included in the automatic operations are grinding of all contours on the shaft and eccentric, indexing the work table and master cam roller, and grinding wheel truing. Straightface cams or those having tapers in both directions may be ground in the automatic cycle.

Automatic functions are controlled from work rotation by a cycle timing mechanism. After completion of the grind, the work table returns to its initial position. As this goes on, the wheel is automatically trued. The truing device compensates for the amount the wheel diameter has been reduced in truing.

Four motors are employed on

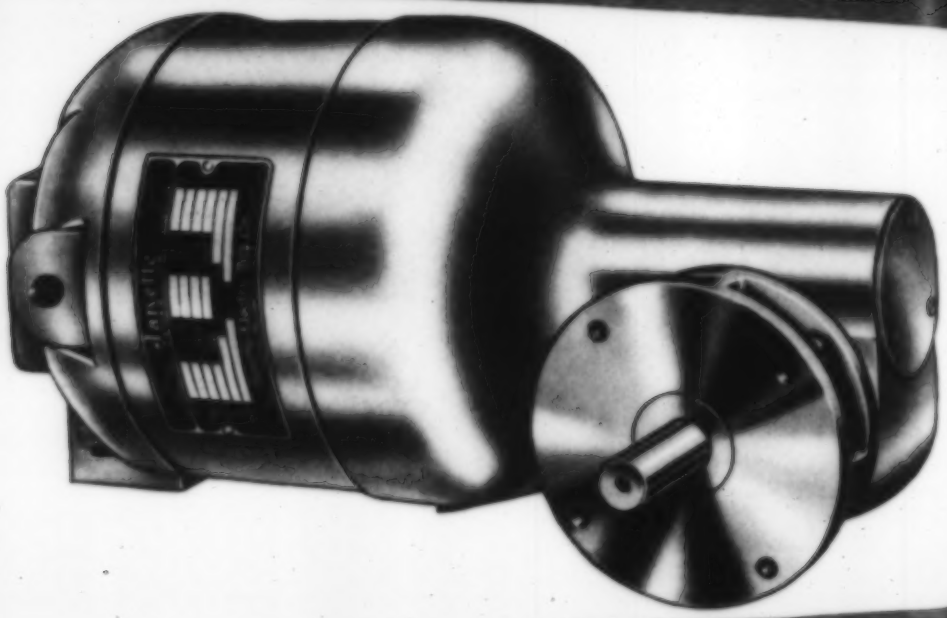


the machine. The grinding wheel is driven by a motor on the wheel

(*Continued on Page* 24)

"THE RIGHT SPEED...THE RIGHT POWER"

Janette GEA



"ALL IN ONE—MADE BY ONE"

Janette Gear Motors are single integral units . . . made by one company, Janette Electric Manufacturing Company.

This simple statement accounts for the many advantages enjoyed by Janette users. And of major importance is the fact that the name JANETTE stands for undivided service responsibility.

The Janette tradition of "The Right Speed—The Right Power" acknowledged throughout industry, has evolved out of the basic engineering principle of balanced performance—possible only with "all in one—built by one" gear motor and speed reducer.

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Janette ELECTRIC MFG. CO.

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OTORS

Janette gives you these "ALL IN ONE" advantages:

Undivided responsibility for design and manufacture of all parts.

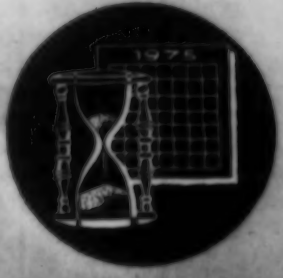
One continuous motor and worm shaft used to obtain perfect alignment and to prevent oil seal leakage.

No back lash movement between motor and worm to cause wear and reduce gear life.

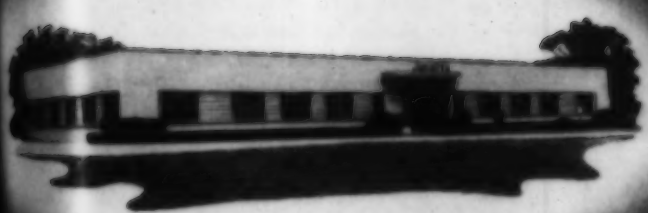
Motor ventilation is designed for blowing air over the gear box for additional cooling.

Motor, gears, shafts and bearings are designed as a balanced unit for balanced performance.

Correct balance of torque between motor and gears results in the right speed and output torque.



Extra capacity bearings used to take the end thrust of the worm and to give longer bearing life.



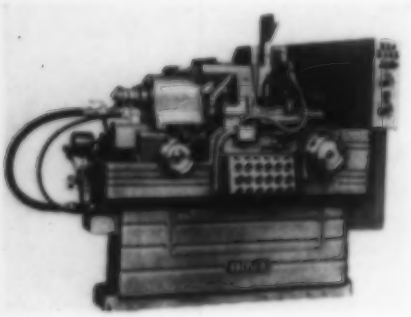
JANETTE GENERAL OFFICE
AND ENGINEERING BUILDING

(*Continued from Page 21*)

slide through matched multiple V-belts. The master cam spindle and work drive motor is mounted on the work drive unit. Hydraulic and lubricating oil pumps and coolant pumps are driven by the other two motors. All electrical equipment is ac operated.

Internal Thread Grinder: Internal threads are ground automatically on this grinder built by Ex-Cello Corp. Equipped with automatic work-handling equipment, the machine receives work from a conveyor, finish grinds and threads, and ejects the completed parts on to an endless belt.

In operation, a loading arm picks

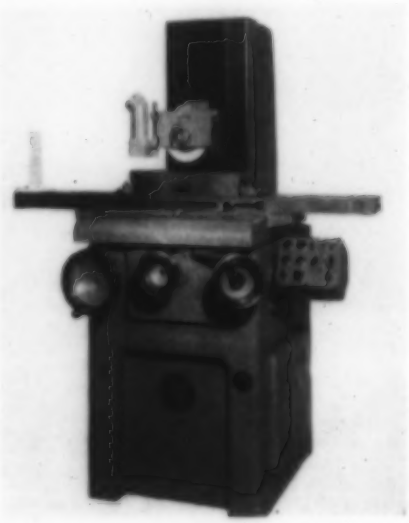


a part out of a loading chute, pivots down and thrusts the work into the chuck. It then rotates the part until a loading key drops into the keyslot. Then the chuck jaws clamp and the arm retracts.

The wheel slide then comes forward and the work rotates and reciprocates in contact with the wheel. When the thread is ground to size, the wheel retracts and the chuck releases and ejects the finished part.

Push Button Grinder: This fully electric-powered, heavy-duty grinder was designed especially for use in production-line work. Built by Reid Bros. Co., the 6 by 18-inch grinder features pushbutton control from a convenient panel.

Dial-controlled speed is variable from zero to 70 fpm. Table reversal is accomplished without reversing the drive motor. Crossfeed is controlled from 0.001 to 7/32-inch. A selector switch controls crossfeed at either or both ends



of the table travel.

Power traverse of the crossfeed, power operated elevating head, and automatic cycle of the crossfeed, are pushbutton controlled.

Thread-Milling Machine: A compact, completely hydraulically operated thread-milling machine is semiautomatic in operation. This 4 by 9 inch machine, built by Hanson-Whitney Co., provides infinitely variable spindle speeds within the normal cutting range to facilitate machining unusual alloys.

Both internal or external cutter heads are available. Internal

or external, straight or tapered threads up to 4 inches in diameter may be produced. Interchangeable lead cams and crossfeed cams are also featured.

A hydraulic collet-closing mechanism is fast operating and has a hole through the center to accommodate long shafts. Cutter head speed is monitored by a tachometer. Dull cutters are detected by a reduction in rpm.

High-Production Grinder: Built-in feedback for gaging and automatic handling are features of this 4-inch concentric grinder built by Landis Tool Co. Inner-ring ball-bearing races have been ground at 250 per hour to a tolerance of 0.0005-inch on diameter. Stock removal was 0.016-inch.

Special automated features of the machine include automatic work loading and unloading devices and a hydraulically operated auto-

matic wheel dresser. A counter on the dresser controls dressing intervals. Special handwheel-feed mechanisms and controls accommodate feedback signals from a gaging device. All sizing information is fed back into the machine for whatever adjustment is required to produce correct part size.

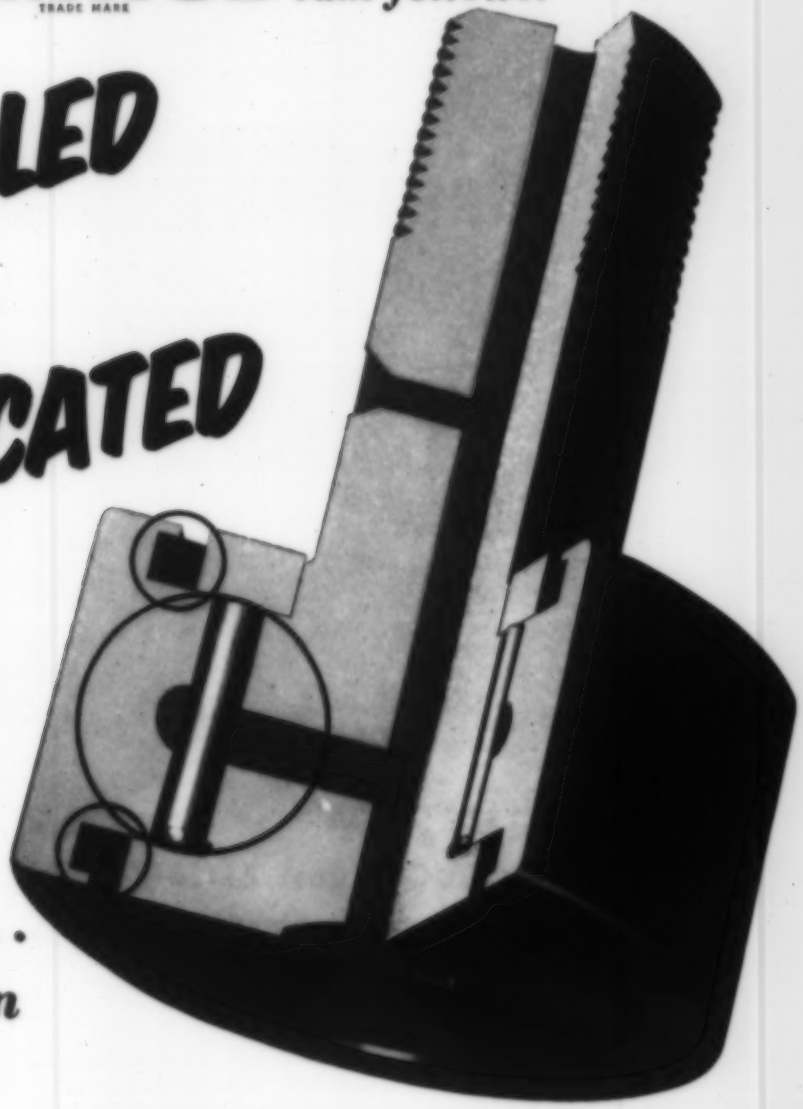
Hydraulic C-frame Press: New C-Press line of oil-hydraulic presses features a specially designed open C-gap frame. Built by Hydraulic Press Mfg. Co., the presses are designed to eliminate encumbrances within the tooling area and provide a maximum amount of room for tooling. They range in size from 2 to 200 tons.

Other features include a high-speed differential circuit and inching control. This control gives the operator precision control of the ram while setting dies.

Three index-table models are

the NEW McGILL® **CAMROL** TRADE MARK *cam follower*

NOW SEALED and PRELUBRICATED



to eliminate contamination . . . save re-lubrication

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SCF series
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bearings

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In one simple assembly, the Sealed CAMROL cam follower bearing gives you three big advantages: 1. capacity to withstand the shock and load of cam action, 2. sealing against contamination that would impair the life of an unprotected bearing, 3. prelubrication that saves frequent relubrication so often undesirable in cam action application. Specially traeated seals are built in at stud and flange ends, and a black oxide finish offers outside corrosion resistance. A channeled reservoir in the outer raceway bore helps store reserve lubrication sufficient in many cases for lifetime service. The new SCF series bearings do not add to the size or weight of standard CAMROL cam followers and are dimensionally interchangeable with them. Ask your McGill representative to show you this newest McGill contribution to the superior performance of your cam actioned machinery, or write to our engineering department for recommendations. Send for Bulletin SCF-55 for more detailed information.

50th Anniversary

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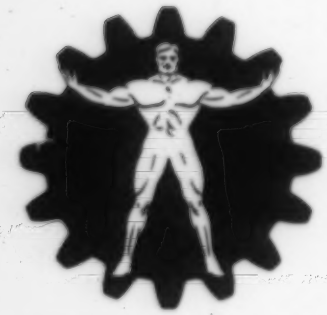
MULTIROL® — GUIDEROL® — **CAMROL** *full type roller bearings*

McGILL MANUFACTURING COMPANY, 200 N. Lafayette Street, Valparaiso, Indiana



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FINE PITCH PRECISION GEARS

LITTLE GIANT—the source that combines engineering experience and advanced low-cost production methods to supply the best possible gears at minimum cost. LITTLE GIANT carefully selects materials to specification. . .produces top quality, high precision gears with the latest machinery for hobbing, shaping, shaving and generating precision fine-pitch gears from raw material to finished gears. . .and maintains precision and quality through rigid inspection procedures after each operation.

SPUR GEARS—up to 4-pitch
HELICAL GEARS—up to 4-pitch
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WORM & WORM GEARS—any size worm threads ground

. . . and MODERN Speed Reducers

Streamlined, modern design and precision gearing that produces exact rated efficiency characterize LITTLE GIANT Speed Reducers. These LITTLE GIANT features assure dependable operation—integral ground worm and worm shaft . . . high nickel-bronze worm gear. . .precision-cut gears of highest quality materials. . .dust-proof, oil-tight, close-grain semi-steel castings. . .oil seals that are leak-proof under high pressure. Bottom worm. . .top worm. Output shaft mounts right, left, up or down (vertical)—easily changed. A wide range of sizes, ratings and torques available.

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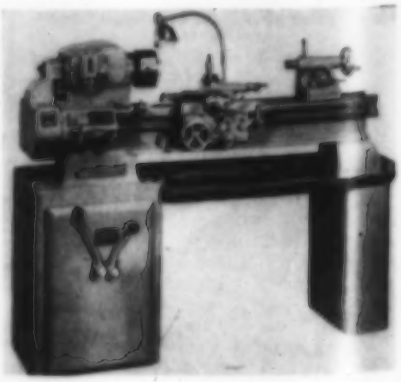
Durakool ALL-STEEL MERCURY *Switches*

available for use with various sizes of the HPM presses. Largest of the three has a 48-inch dial and a work circle of 36 inches. Its speed is in-

finitely adjustable up to 60 indexes per minute.

In operation, oil from the press power unit is diverted to the index table circuit at the end of each ram cycle. A positive interlocking feature permits the units to function in synchronization without repeat cycles.

Pedestal-Mounted Lathe: An improved "U" type drive is a feature of this Sheldon Machine Co. Inc.



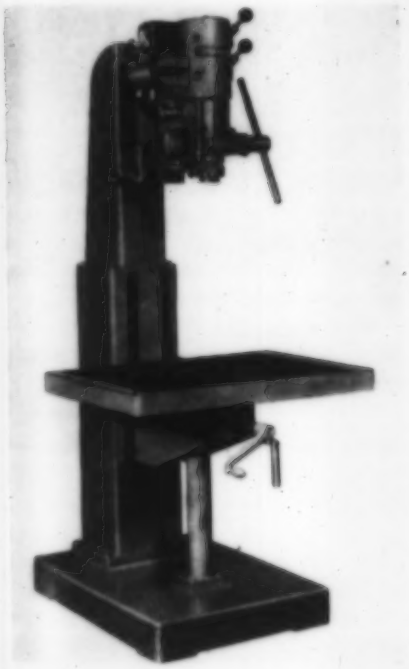
lathe which enables quick shifting to preselected speeds. External shifting levers provide 8 spindle

speed changes from 50 to 1200 rpm.

Other features include a ratchet-action tailstock lock and double neoprene cog V-belts to the spindle. Swing of the model illustrated is 13 inches.

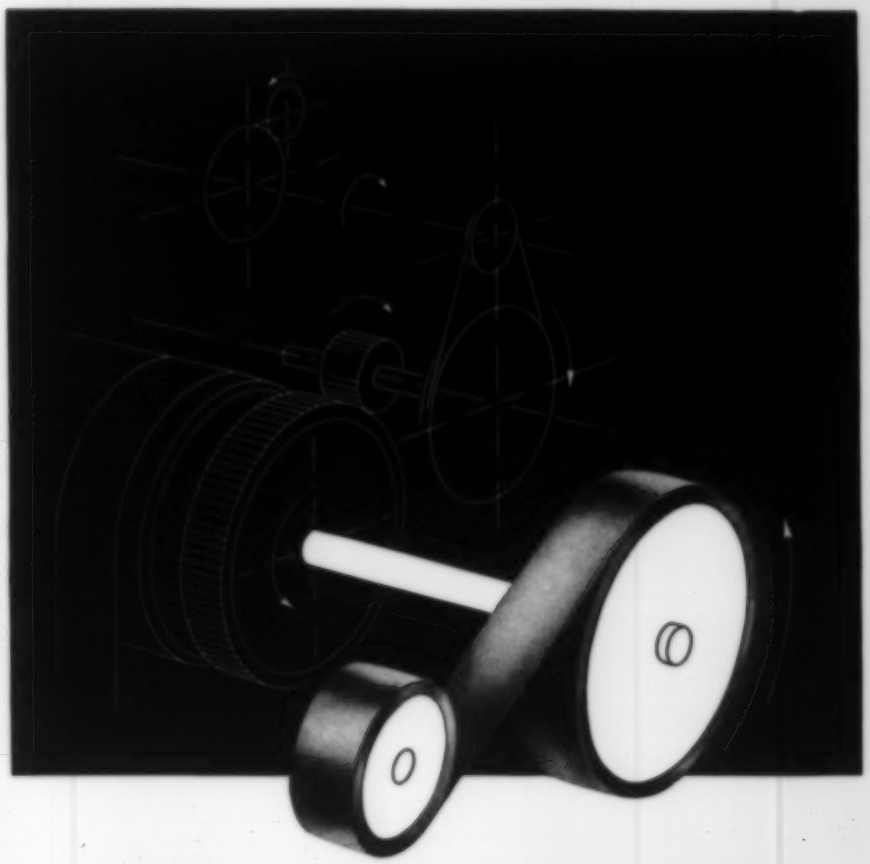
Box Column Drill Press: Completely gear driven, this machine has eight spindle speeds from 95 to 1200 rpm. Any speed can be selected instantly, even while the drill press is running. The spindle is equipped with an automatic drill ejector, eliminating the need for a conventional drift to remove drills or tools.

Built by I. O. Johansson Co., the machine is equipped with a



2-hp motor. Drilling capacity is 1¾ inches in cast iron. Maximum distance between the spindle nose and table is 28 inches. Added capacity is available because of the machine's unusual design. The motor, gear housing and spindle assembly are built in one unit so the drill head can be raised or lowered on its support column. It can also swing sideways through an arc of 180 degrees.

Hydraulic Openside Shaper: Introduced by Rockford Machine



DRIVE IT WITH A NEG'ATOR®

constant-force spring

Ideal for use as a powerful, constant-torque motor is the NEG'ATOR Spring, the revolutionary constant-force spring component which is giving design engineers new ideas.

They're using the NEG'ATOR Spring as a motor in two ways. A light torque motor is made by winding the NEG'ATOR Spring around two drums of unequal size. The tendency of the material to recurl to its *preset curvature* around the smaller drum imparts a constant output torque to the shaft of the larger (output) drum. A more powerful and efficient motor is made as shown above—by *reverse*-bending the free end around the output drum.

Think of how products can be improved, problems solved with a long-running, constant-torque motor. An aircraft designer with a critical counterbalance problem found out. So did a manufacturer of self-retrieving, 50-foot, steel tapes . . . a motion picture camera maker . . . an engineer who developed a new precision mechanical computor . . . many others with drive unit, long deflection, and counterbalancing design problems.

And, so will you when you get the full story. Ask us for a copy of Bulletin 310N, "The Story of the NEG'ATOR Spring." We'll send it immediately without cost.

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(near Philadelphia)

SPRINGS • STAMPINGS • TEST APPARATUS

you can
Count
▶ BETTER
▶ LONGER
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with
PIC-600
TWINS

50 million count life — conservative rating.

1000 counts per minute — higher speeds with suitable actuation.

7 watts power consumption

Balanced armatures (for accurate performance on airborne equipment).

Quiet operation. No AC hum when energized.

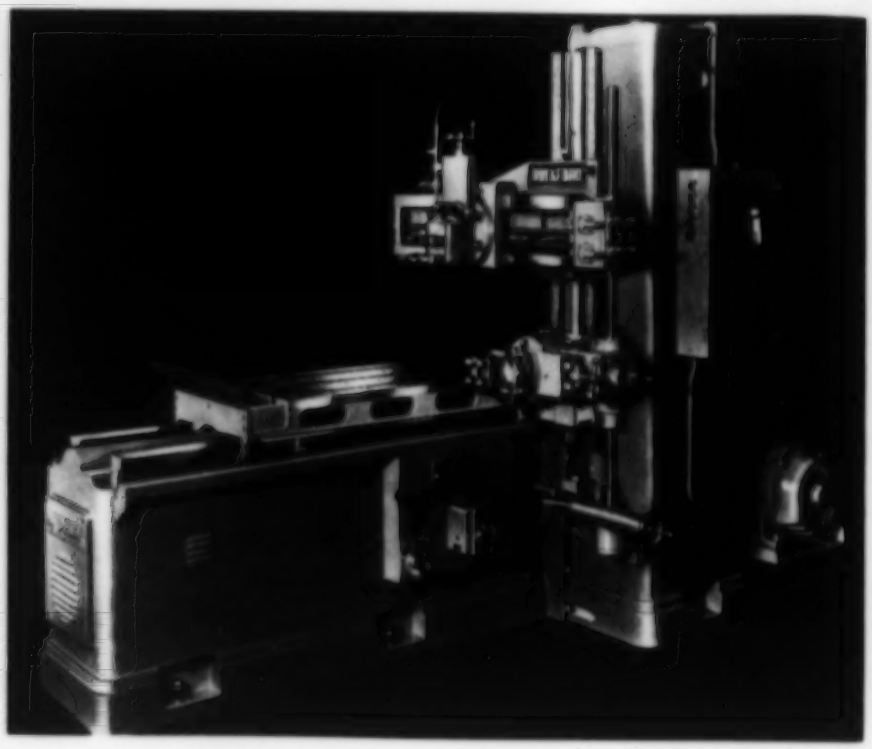
Dust-resistant, tamper-proof housing. One-piece die-cast enclosure with close fitting cover secured with concealed screws.

Available in Basement and Standard-mount Models for 60, 40-50, and 25 cycles, also DC all voltages to 150.

Ask your PIC Representative or send for literature

PIC
PRODUCTION INSTRUMENT CO

702-08 W. Jackson Chicago 6, Illinois

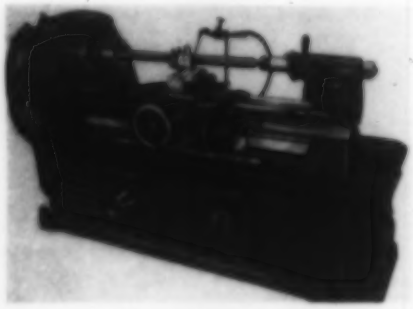


Tool Co., this machine is said to be the only one of its kind made in the U. S. On work where the stroke required is over 28 inches long, conventional shapers have certain disadvantages. Bearing surfaces tend to wear and inaccurate work results.

According to Rockford, these difficulties are overcome by reciprocating the work rather than the cutting tool. All the work is carried on a box-section table supported by a double-length bed. Easier setup and handling is a result. Planer accuracy is also provided with this method.

Hydraulic drive and feed provide simple control and infinite speeds and feeds.

Automatic Threading Lathe: A new type of single-point thread-cutting machine is said capable of



cutting threads 2000 per cent faster than standard machines. This machine is designed to cut 30 inches of 2-inch diameter stock in a total time of 2½ minutes.

Capacity is 30 inches of actual thread length at diameters up to 12 inches. Both internal and external threads may be cut, either right or left handed, taper and multistart.

Loading and unloading is the only manual part of the operation. The cycle is fully automatic. Up to 100 passes per minute may be preset, including a diminishing feed per pass for roughing and finishing during the cycle. Average setup time is about 10 minutes.

According to Man-Au-Cycle Corp., builders of the machine, working speeds up to 2000 rpm are possible. These high working speeds are expected to permit full utilization of carbides.

Drilling and Tapping Machine: Designed for heavy-duty drilling and tapping operations on a con-

Superbly Machined G. S. Planetary Gearing Transmits Power in Clarke Floor Maintainers

Clarke Floor Maintainers take a terrible beating! Buildings use them night after night for years, with little or no down-time. Big contributor to the spectacular power, speed and low operating cost of this rugged machine is the Planetary Gearing *superbly machined* by G. S. ★ If you have power transmission problems in which Small Gearing is involved, check up *now* on *"G. S. Free Consulting Service"*. Let our specialists recommend the ONE best application for the job you describe. Write today!

SEND FOR.. *our 8-page Small Gearing Guide. It illustrates and describes over 80 different types and applications of G. S. Small Gears, from 8 to 96 dp. Ask for it on company letterhead, please.*

40 Years of Specializing in Small Gearing!

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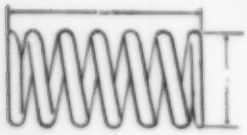
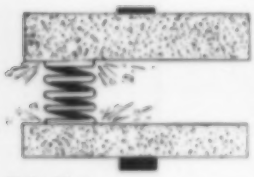
AUTOMATIC SPRING

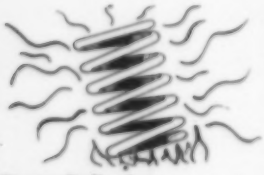


Designing

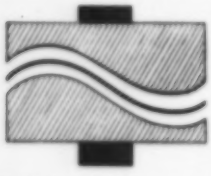
Coiling



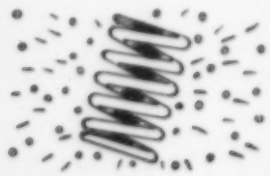
Grinding



Stress Relieving



Forming



Shot Peening

big enough • • • yet small enough

AUTOMATIC SPRING is the ideal size company to make your springs. We're big enough to have a complete range of the best modern equipment. We have a full range of spring coiling machines, a grinding department second to none, stress relieving, shot peening, multi-slide, stamping and finishing facilities, and a complete tool room. And we have the capacity to handle large runs.

But AUTOMATIC SPRING is also small enough to give your job personal attention. Top expert advice is available on your design or engineering problem. From the Production Manager right down to the operator, everyone knows your job and what is wanted. And when you need shipping information, it is available immediately.

So we feel safe in boasting that AUTOMATIC SPRING gives personalized attention. We are big enough—yet small enough!

Send for new illustrated brochure, giving information for specifying springs and other data.

for quality springs "Automatically" think of

AUTOMATIC

SPRING COILING CO.

4058 West Thorndale Ave., Chicago 30, Ill.

tinuous production basis, this machine features infinitely adjustable speeds up to 2000 rpm. Capacity is 1½ inches in cast iron. Overhang is 12 inches.

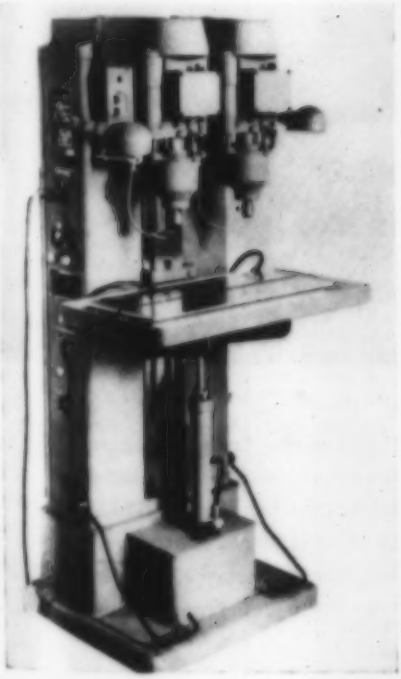
Other models built by Edlund Machinery Co. feature infinitely adjustable speeds up to 10,000 rpm, with up to four spindles available. An automatic-indexing work table with a time control at each station may also be used in conjunction with the machine.

Double-Disk Grinder: High-production precision grinding of parallel flat surfaces is a feature of this 30 inch double-disk grinder. Loaded and unloaded automatical-

ly, this machine can grind 885 pump gear blanks per hour. Made by Gardner Machine Co., the grinder is equipped with a rotary work carrier and automatic size control.

Workpieces are loaded into the machine by a Feedall hopper feeder consisting of an elevator with a roll-chute delivery. Parts are pneumatically transferred from a roll-chute to an 18-station rotary carrier. The carrier can be adjusted to produce 594, 780, or 885 parts per hour. Finished parts are discharged through a chute into a metal basket.

Combination Drilling Machine: Universal vertical drilling, tapping and threading machines made by Snow Mfg. Co. have automatic transfer and selector controls. An air-operated work table, an automatic belt-tensioning device, limit switch controls and sensitive air-



pressure and feed arrangements minimize human error and provide constancy of operation.

Range of tap sizes is from No. 0 tap to 1 inch (coarse) to 1½ inch (fine). Drill sizes from No. 60 through ⅜-inch may be accommodated. Range of external thread sizes is from 3-48 to 1 inch on

(*Continued on Page* 36)

PANELOC announces a new rotary latch

Saves Cost • Saves Time
Saves Space • Saves Weight

This new Paneloc Rotary Latch is a simple and economical, strong and durable fastener for access panels, electrical control panels, inspection doors, machinery doors, and other hinged or removable covers. It permits a larger access opening, operates quickly with a quarter-turn. Entire assembly on access panel itself, eliminating many installation steps; no special tools required. Only four simple parts; made of steel, cadmium plated. Three standard sizes now available, more to be added. Special sizes and finishes available on order. Cost very low, performance unsurpassed. Write for a catalog and price list for your file.

PANELOC...America's most versatile line of aircraft fasteners . . . Rotary Latches, Styles 1, 2, and 3 Panel Fasteners, High Performance Fasteners, Snap Fasteners.

PANELOC—A product of Scovill

Scovill Manufacturing Company, Aircraft Fastener Div.
50 Mill Street, Waterbury 20, Connecticut

Please send me fastener catalogs checked:

( ) Rotary Latch ( ) Style 3 (MIL-F-5591A)
( ) Styles 1 & 2 (MIL-F-5591A) ( ) High Performance (NAS-547)
( ) Snap Fasteners (AN 227)

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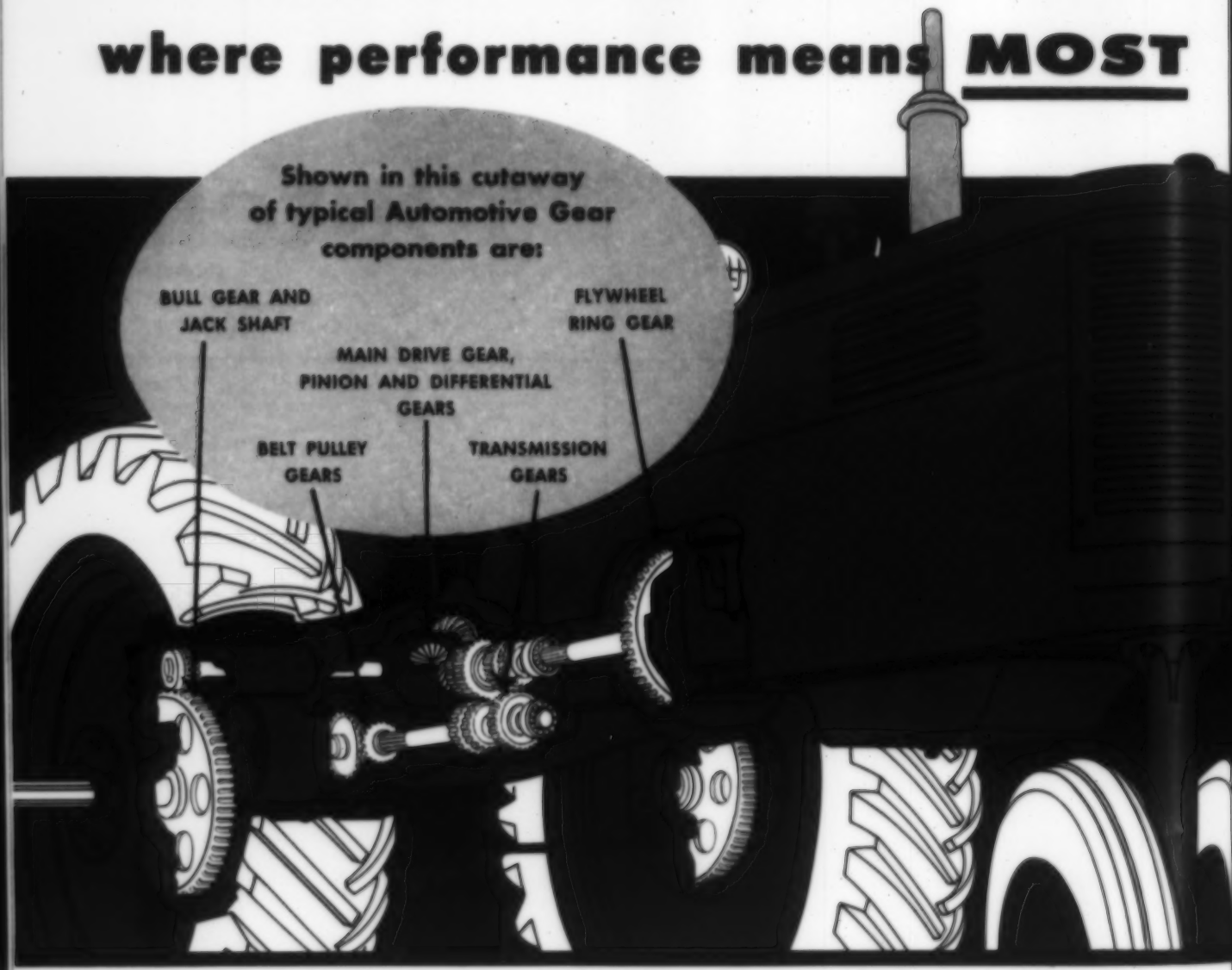
GEARS

where performance means MOST


Shown in this cutaway of typical Automotive Gear components are:
BULL GEAR AND JACK SHAFT
FLYWHEEL RING GEAR
MAIN DRIVE GEAR, PINION AND DIFFERENTIAL GEARS
BELT PULLEY GEARS
TRANSMISSION GEARS

When gears are used to transmit power there's no standard of comparison equal to on-the-job-performance. This is particularly true of farm machinery, where the dependability of gears is essential in maintaining the planting, cultivating and harvesting schedules.

Automotive Gears are used in a wide variety of the best-known, best-made farm machines. Their record is worth your inspection—no matter what your gear problem may be. This is particularly true if you are considering a source with the experience, the engineering service, and the facilities to serve as your "gear department." Just write or phone.

DOUBLE DIAMOND GEARS

FOR AUTOMOTIVE, FARM EQUIPMENT AND GENERAL INDUSTRIAL APPLICATIONS
GEAR-MAKERS TO LEADING MANUFACTURERS

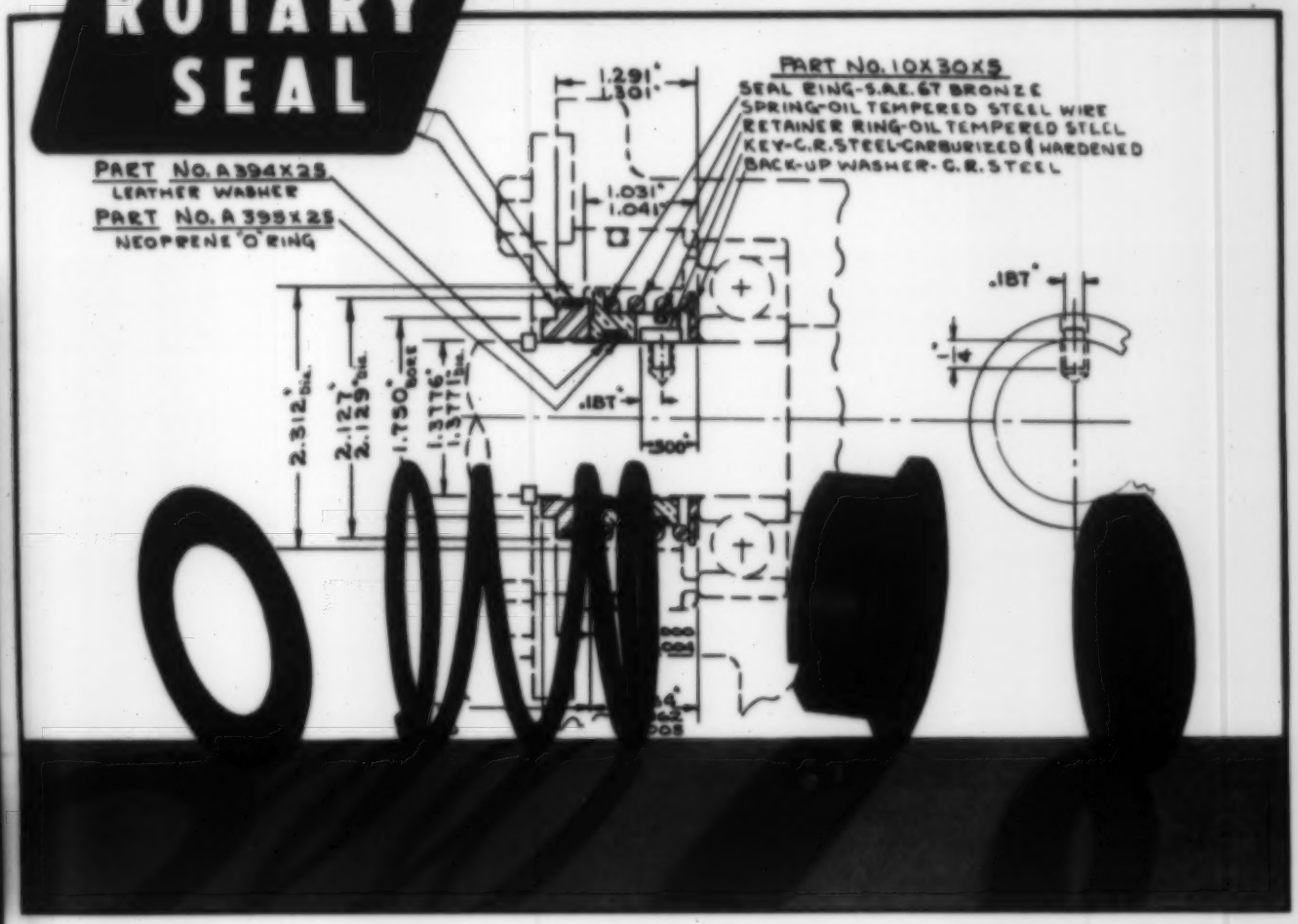
Automotive Gear Works, inc.

ESTABLISHED IN 1914

RICHMOND, INDIANA

ROTARY SEAL

SPECIALIZED SEAL ENGINEERING



is developing new ways to assure top performance in HIGH-PRESSURE HYDRAULIC OIL PUMPS

In modern pump design, pressures keep climbing, overall sizes keep shrinking—and the Shaft Seals must be better designed to handle tougher operating conditions.

Take a Seal like that illustrated: it's one of a series developed by ROTARY SEAL engineers, for heavy-duty pumps which activate big 'dozers and similar equipment. High pressures provide higher out-put efficiency; and the Seal must take the whole load—no shunting or bypassing part of it—yet must be designed to take up less space in extra-compact units.

You can't reach back on the shelf for a Shaft Seal when your pump—or your compressor, or whatever your unit may be—must measure up to tougher modern specifications. It takes a *custom-designed* Seal—fitted in every detail to the specific job at hand. ROTARY SEAL specializes in developing and manufacturing Seals to meet such problems, by applying the basic ROTARY SEAL principles which opened the way to successful mechanical Shaft Sealing when this company introduced them years ago.

Major assignments for important Seal developments are keeping us mighty busy at present; but if special difficulties are besetting *your* development programs, and production quantities of Seals are involved, we'll be glad to help if we can.

THE ROTARY SEAL COMPANY

mechanical seals for rotating shafts

Shaft-Sealing with Certainty

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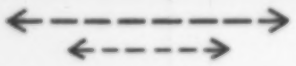
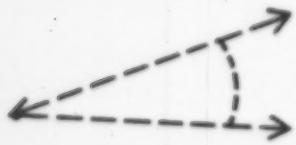
HYDRECO Oil Power

OFFERS ENGINEERS— CUSTOM DESIGN in HYDRAULIC CYLINDERS!



Even simple functions may entail special configurations to give maximum results...



Or, when the function involves motion in more than one direction, custom design develops mountings to suit the application...

Or cylinder movement in any direction, and many other variables are yours with HYDRECO Custom Design.

For the engineer whose target is equipment that will outperform any comparable unit—the special facilities offered by HYDRECO can materially assist in attaining the objective. Not with so-called "standard" cylinders but rather with cylinders custom engineered and built to do the specific job.

Requirements of space, mounting, or hydraulic connections that could never be met by "standard" cylinders, can be fulfilled easily through custom designing.

And too, HYDRECO's variety of experience in designing and building special hydraulic components in volume production can keep the product costs within the budget.

That which is true of HYDRECO Cylinders is equally true of HYDRECO Pumps, Motors and Valves. To improve the performance of existing equipment or to add functions *and* complete dependability to projected designs—look to HYDRECO Oil Power!

WRITE— *for full information today on HYDRECO Pumps, Motors, Valves and Custom Built Cylinders.*

HYDRECO DIVISION
THE NEW YORK AIR BRAKE COMPANY
1106 EAST 222nd STREET • CLEVELAND 17 • OHIO
INTERNATIONAL SALES OFFICE, 90 WEST ST., NEW YORK 6, N. Y.

News Roundup

(*Continued from Page* 31)

straight threads and to ½ inch pipe on tapered threads.

With the two-spindle machine shown, a combination of spindles may be used to cover the ranges listed.

Vertical Turret Lathe: Featuring instant-powered remote-control shift, this new Giddings & Lewis vertical turret lathe uses a "joy stick" to control direction of feed and traverse movements. Rams are screw fed. Each head has independent feed and traverse

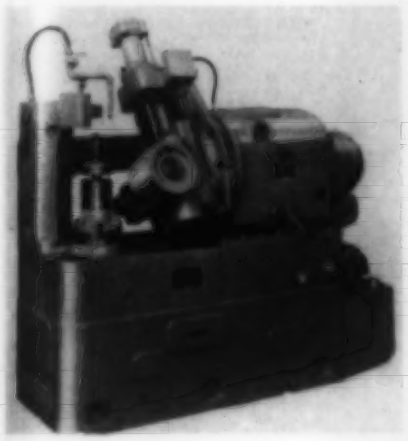
with directional controls to both ram and saddle.

Specially designed standard swiveling turret and swiveling ram heads are counterbalanced. A safety device prevents movement of the turret except by use of the index crank. Therefore, large bars causing an out-of-balance condition can be used. Head settings are adjustable to within 1 minute of arc.

Table speed is adjustable from 6 to 320 rpm in 24 geometric steps. Drive motor is 50 hp. The turret lathe is capable of changing speeds in fly or cut, thus saving machining time.

Helical Gear Hobber: This machine was designed for automatic high-speed mass production of helical gears. Developed by Gould & Eberhardt Inc., the machine feeds

the hob tangent to the helix of the gear being cut. Two basic cutting styles are available. One uses a feeding cycle which provides three feed rates in series, two successive



fast-enter feeds at different rates, followed by a hobbing feed. The other starts with a fast-enter infeed followed by a hobbing feed tangent to the helix.

A hydraulically-operated hobbing feed eliminates the need for a lead screw. No differential or lead cam is required, and lead and feed change gears and related calculations are avoided entirely.

The fully automatic cycle is actuated by a single pushbutton. Only loading and unloading are manual. However, automatic loading is possible.

Right or left-hand helical gears up to a 45-degree helix angle may be produced. Hob speeds up to 550 rpm are available. Capacity is from 2¾ inches to 10 inches diameter, 8 and 14 NDP with 6-inch maximum face.

Double-Housing Planer: An actual tool speed of 400 fpm is the outstanding feature of this double-housing planer. Made by Giddings & Lewis, the machine is said capable of unusual precision at these high speeds.

Dual saddle and slide controls and power crossfeed to side heads are among other features listed. Extra-high pneumatic tool lifters for both rail and side heads are provided.

A special high-horsepower ad-

Consider DUDCO Double Pumps with Valve Panels from the Standpoint of Their Ability to—

HELP SELL YOUR EQUIPMENT!

CONTROLLED FLUID POWER Contributes Added *Flexibility* to Machine Tool Performance

DUDCO PF-100 Series Double Pumps with combination relief and unloading valves provide high circuit flexibility through either automatic or external pilot control. For example... in a "hi-lo" circuit, large volume delivery is available for a fast traverse cycle. Then, during the feed cycle, when small volume is required, one pump section unloads automatically... saving dollars in horsepower! These pumps can also be operated on separate circuits . . . each circuit protected by its own relief valve.

TWO VANES ARE BETTER THAN ONE

The hydraulically counterbalanced DUAL-VANES in DUDCO Hydraulic Pumps eliminate wear producing loads normally caused by unbalanced hydraulic forces and vane acceleration. DUAL-VANES also maintain MULTIPLE SEALING BARRIERS to slippage and power loss. DUAL-VANES are a patented and exclusive DUDCO feature.

DUDCO Pumps can operate *continuously* at 2000 psi. Their exclusive "Dual-Vane" feature and advanced design combine to assure long, trouble-free performance and maximum simplicity in servicing. Thus, they are a natural choice for a wide variety of high production equipment, including: Machine Tools, Hydraulic Presses, Die Casting and Plastic Moulding Machines, Closing and Clamping Devices and other functions calling for controlled variation in Pump volume.

The PLUS factors in DUDCO Pumps weigh heavily at the sales end—so, WRITE... get the facts on DUDCO Dual-Vane Hydraulic Pumps and Fluid Motors.

DUDCO DIVISION
THE NEW YORK AIR BRAKE COMPANY
1706 EAST NINE MILE ROAD • HAZEL PARK • MICH.
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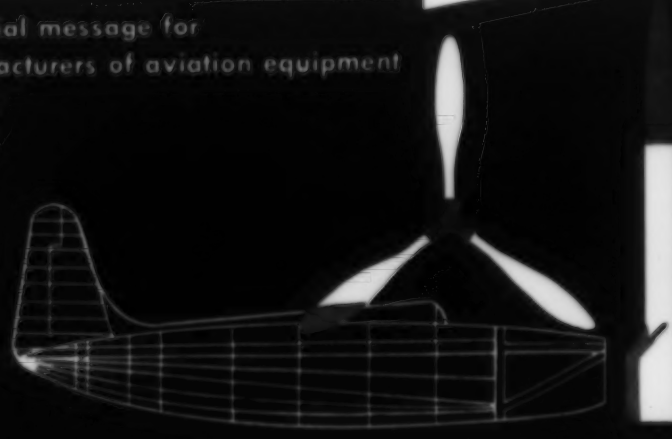
a special message for
manufacturers of aviation equipment



need a finish for
light metal parts? IRIDITE

Here's the finish that combines corrosion resistance and paint adherence with extreme ease of application. It can be welded or soldered with no difficulty and presents no problem in "patching" scratches, marks or scraped sections. Here's what you can do with Iridite:

ON ZINC AND CADMIUM you can get highly corrosion resistant finishes to meet any military or civilian specifications and ranging in appearance from olive drab through sparkling bright and dyed colors.

ON COPPER . . . Iridite brightens copper, keeps it tarnish-free; also lets you drastically cut the cost of copper-chrome plating by reducing the need for buffing.

ON ALUMINUM Iridite gives you a choice of natural aluminum, a golden yellow or dye colored finishes. No special racks. No high temperatures. No long immersion. Process in bulk.

ON MAGNESIUM Iridite provides a highly protective film in deepening shades of brown. No boiling, elaborate cleaning or long immersions.

AND IRIDITE IS EASY TO APPLY. Goes on at room temperature by dip, brush or spray. No electrolysis. No special equipment. No exhausts. No specially trained operators. Single dip for basic coatings. Double dip for dye colors. The protective Iridite coating is not a superimposed film, cannot flake, chip or peel.

WANT TO KNOW MORE? We'll gladly treat samples or send you complete data. Write direct or call in your Iridite field Engineer. He's listed under "Plating Supplies" in your classified phone book.

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News Roundup

justable-speed drive is provided with a table speed range from 25

to 400 fpm. This wide range and adjustment provides flexibility needed for either high-speed steel or carbide tools.

Six-Spindle Chucking Machine: Completely automatic, this six-

spindle chucking machine is designed for high-speed production of automotive type pistons. Built by Baird Machine Co., the unit, along with a Baird vertical continuous lathe, makes up a high-production tooling unit.

Crankshaft Gaging Machine: Up to 43 dimensions and conditions on an automobile crankshaft may be inspected quickly and accurately with this device. Made by Sheffield Corp., the gage unit is especially useful in making precise measurements in high-speed production op-

erations.

This 36-column unit may be adjusted to accommodate changes in

design without costly modification. An 18-column gage is also available. This latter unit has been adapted to inspection of jet engine blades.

Superfinishing Machine: Completely automatic machine is de-

signed for superfinishing of inner and outer roller-bearing races. Made by Gisholt Machine Co., the superfinisher removes 0.25-inch of stock in 30 seconds. The surface is finished to 3-5 microinches. A large variety of sizes and styles may be handled by this single machine.

Solar Engineering Exhibit is being planned in conjunction with the World Symposium on Applied

(*Continued on Page* 42)

REEVES

the right speed for every need!

fractional HP Vari-Speed
MOTODRIVE

compact, attractive design

Within streamlined, metallic blue housing is REEVES' "weatherized" motor, time-tested speed changing mechanism, and heat-treated helical gear speed reducer. Maximum space for vertical model only 16⅛" x 21½" x 11½". Other models equally compact.

simple, accurate operation

14-turn handwheel on Speedial indicator gives you stepless, accurate speeds from 3 to 4660 rpm's—within a 2:1 to 10:1 speed range. Electric remote or automatic controls also available.

45° Model

Horizontal Model

versatile application

Select your *exact* needs from 112 assemblies: ¼, ½ or ¾ hp. units; horizontal left or right, vertical, or 45° left or right models; horizontal or vertical down output shaft.

Write Dept. H19a-M543 for complete bulletin.

REEVES PULLEY COMPANY • Columbus, Indiana
Division of RELIANCE Electric and Engineering Co.

Only aluminum

The Nu-Jett Pencil-type Grinder operates at 100,000 rpm. It grinds, deburrs, cuts, etches, polishes, engraves. Has only one moving part—the lightweight aluminum rotor, which floats on a cushion of air. Grinder unit weighs only 5¾ ounces. The Nu-Jett Filter and Oiler unit, also made of Kaiser Aluminum, assures clean air for the grinder, simultaneously with accurately metered oil in mist form. Units are perfect example of how Kaiser Aluminum makes possible high quality, precision products at reasonable cost.

Nu-Jett Products Corporation
1355 Michigan Ave. N.E.
Grand Rapids, Michigan

GENERAL MANAGER OF NU-JETT, Mr. William W. Peterson, says:

"Aluminum saved us 27% in costs! Aluminum's lower initial cost was a big factor in this saving. But it also provided other important savings. Its light weight gives us appreciable savings in shipping costs, including the lighter weight shipping container. Brass would have required a clear baked enamel for protection. Steel could not be considered for this product because compressed air, which runs the tool, carries moisture which would quickly rust the metal.

"One more thing: machined aluminum gives the Nu-Jett grinder a quality that puts it in a class by itself."

parts are good enough for this amazing grinder!

BECAUSE of the high performance and quality requirements of the Nu-Jett pencil-type grinder, made by the Nu-Jett Products Corporation, Grand Rapids, Michigan, *only* aluminum screw machine parts could be successfully used.

Nu-Jett found that Kaiser Aluminum was the perfect material for their grinder and filter unit. It was not only economical in raw material outlay and production costs but actually *permitted a design of higher performance characteristics!*

DESIGN ENGINEER OF NU-JETT, Mr. Charles V. Johnson, says:

"Aluminum made this grinder possible! Obviously, a pencil-type grinder that has a speed of 100,000 rpm and yet is extremely durable makes metal selection of paramount importance. In every way, aluminum was superior to other metals. The light weight aluminum rotor attains maximum rpm within 4 seconds, thus minimizes starting lag. Too much lag would result in the rotor turning in the critical vibration zone long enough to cause excessive wear on the bearings. Once started, the light aluminum rotor actually floats in the air stream. By using aluminum for virtually every part, we make the tool easy to use, with less operator fatigue.

"Aluminum's anodic finish is more resistant to the attack of salt-laden hand moisture. These, of course, are only a few of the many rewarding design experiences we have had with Kaiser Aluminum."

SCREW MACHINE FOREMAN AT NU-JETT, Mr. Arthur Moorhus, says:

"Aluminum speeds our production! In the first place, we have no difficulty in machining aluminum at the same speeds and feeds as brass, and often faster.

"We use conventional tools and tool angles for aluminum. We find that *Kaiser* Aluminum Rod runs extremely uniform. With our experience with aluminum, we like it as well as any other metal to machine."

THE Nu-Jett story is just one of many that emphasize this point: when you specify *aluminum* screw machine parts you often get *better* parts for *less money*.

A pound of Kaiser Aluminum screw machine stock gives you *three times* as many parts as a pound of brass or steel.

And these parts provide you with a unique combination of advantages, which include lightness with strength, handsome finish, corrosion resistance, excellent heat and electrical conductivity.

For more information or assistance, look for our local number in the classified telephone directory under the heading "Aluminum" or contact one of our many distributors. Kaiser Aluminum & Chemical Sales, Inc. *General Sales Office*, Palmolive Bldg., Chicago 11, Illinois; *Executive Office*, Kaiser Bldg., Oakland 12, Calif.

Kaiser Aluminum

setting the pace—in growth, quality and service

ILSCO CONNECTORS

All these . . . and more . . . for
YOUR BEST CONNECTIONS

U/L AND CSA TESTED	HI-RUGGED STRENGTH
PURE COPPER	RE-USABLE
100% CONDUCTIVITY	ALL WIRE SIZES
COOLER OPERATION	ECONOMICAL

MAKE YOUR PRODUCT PERFORM BETTER

WRITE FOR
80-PAGE CATALOG

ILSCO CORPORATION
5752 Mariemont Ave.
CINCINNATI 27, OHIO

GENERATED HELICAL ROD

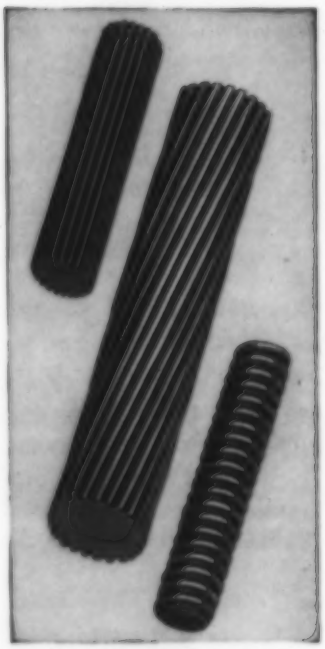
Mass Gear can generate spur, helical and worm pinion rod in all types of material including plastic.

Mass Gear can also produce any type of serrated or special form rod that can be generated.

These rods are available up to 6 feet in length, from 5/32" to 1 ¼" in diameter.

Mass Gear products are made to A.G.M.A. standards, thus insuring uniform quality.

Illustrated brochure showing interesting designs and suggestions available upon request.



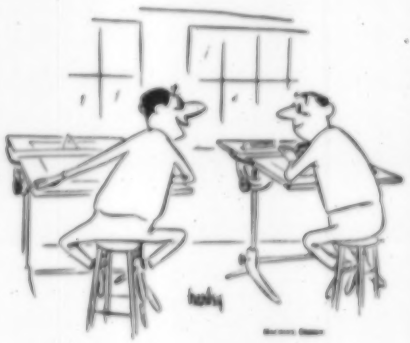
Massachusetts Gear & Tool Co.
WOBURN, MASS.

News Roundup

(*Continued from Page 39*)

Solar Energy to be held in Phoenix, Ariz., from October 29 through November 13, 1955. Equipment illustrating recent developments in the field of solar engineering will be on display. Included will be a 5 to 10-hp sun-driven engine, a production model of a solar water-heating collector and steam generator, and a solar food-cooking oven.

Other devices to be exhibited include solar stills to convert salt water into fresh water. Several high-temperature furnaces will be displayed. A sun-operated portable radio transmitter as well as many varieties of sunlight measuring instruments will be shown.



"Let's design a machine that does absolutely nothing."

New Corrosion-Resistant Alloy Announced

Zirconium Alloy Developed For Nuclear Reactor Use

GENEVA, SWITZERLAND — Development of a new alloy that withstands corrosion encountered in nuclear reactor service was announced at the recent International Conference on Peaceful Uses of Atomic Energy. Developed by Westinghouse Electric Corp., the new alloy resists the extremely corrosive action of high temperature and high-pressure water. According to the report, only 0.0001-inch of corrosion can be measured in a year's time.

Called Zircalloy-2, the new alloy is a result of finding a combina-

tion of alloying material to produce a metal capable of withstanding the specified conditions. Westinghouse engineers found that even an infinitesimal amount of an impurity greatly affected corrosion resistance.

Two operations were performed to obtain pure zirconium. However, even this doubly-purified metal did not have the corrosion resistance desired.

Westinghouse engineers began adding small amounts of other metals to zirconium to further increase its corrosion-resistant properties. Of all the elements examined, tin was found to be the most satisfactory. Desired properties were finally obtained with an alloy containing 1.5 per cent tin, 0.12 per cent iron, 0.1 per cent chromium and 0.05 per cent nickel.

Ford Motor Co. has announced plans for a multimillion dollar engineering and research building to be constructed in Dearborn. The new structure, to be called the Scientific Laboratory and Research Building, is scheduled for comple-

tion in 1957. A newly formed product study group plus Ford's present engineering research and advanced vehicles departments will occupy the building.

Nuclear Science and Engineering Corp. has become the first private American firm producing radioisotopes in cyclotrons and supplying them to industrial and medical users. For the past six years, the only U. S. supplier of cyclotron-produced radioisotopes has been the Atomic Energy Commission. The AEC has announced that it is now discontinuing its program.

Under the Nuclear Science and Engineering program, government

rig

with
BIJUR
AUTOMATIC
LUBRICATION

Bijur Automatic Lubricating Systems designed into your machines *from the start* help you build an early lead in customer satisfaction.

And with Bijur you are *right* because for a quarter of a century Bijur Automatic Lubricating Systems have been part of efficient production programs.

Your customers prefer automatic lubrication in the equipment they buy because it increases production and reduces operating costs. Built into your original plans for machinery production, a Bijur Automatic Lubricating System can work for you by increasing customer acceptance, assuring bearing safety, and contributing to operating efficiency.

Call in a Bijur lubrication engineer. He is ready to help with your technical problems.

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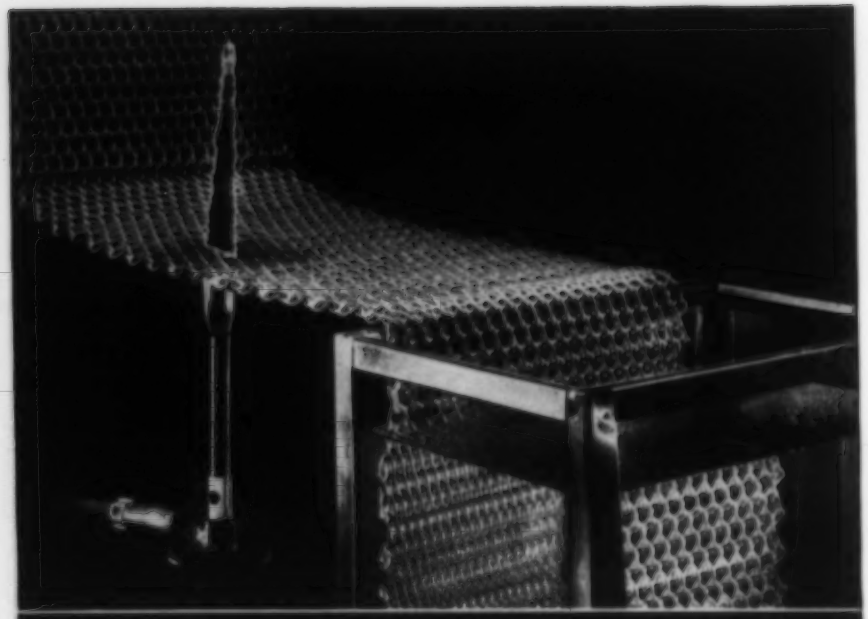
BIJUR
LUBRICATING CORPORATION
Rochelle Park, New Jersey

Pioneers in Automatic Lubrication



HEATPROOF! RUSTPROOF!

Cambridge

WOVEN WIRE CONVEYOR BELTS

permit continuous heating, cleaning, washing

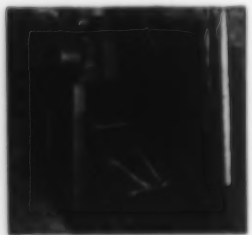
All-metal belt . . . corrosion resistant and impervious to damage at temperatures from sub-zero to 2100° F . . . withstands most severe conditions in heat treating, food processing, chemical manufacture, ceramic firing.

Whether you're designing machines for your own operation or for resale, you can eliminate batch handling, cut costs, provide uniform, continuous production at controlled rates of speed with moving woven wire belts.

Open mesh construction of Cambridge Woven Wire Conveyor Belts lets process atmospheres circulate freely for uniform cooling, heating, drying . . . provides flash drainage of solutions for rapid washing, quenching, cleaning, draining. Cambridge belts have no seams, lacers or fasteners to wear more rapidly than the body of the belt . . . no localized weakening.

No matter how you look at it, CAMBRIDGE Woven Wire Conveyor Belts are invaluable aids to AUTOMATION . . . help beat your biggest competition, COST. They are made in any size, mesh or weave, from any metal or alloy. Special raised edges, cross-mounted flights and other surface attachments are available to hold your product during movement.

Call in your Cambridge Field Engineer to discuss how you can cut ultimate costs by continuous operation. You can rely on his advice. Write direct or look under "BELTING, Mechanical" in your classified phone book.



CONTINUOUS QUENCHING—of small or large parts on a Cambridge belt is faster and cheaper.

ASK FOR FREE 130-PAGE REFERENCE MANUAL illustrating and describing woven wire conveyor belts. Gives mesh specifications, design information and metallurgical data.

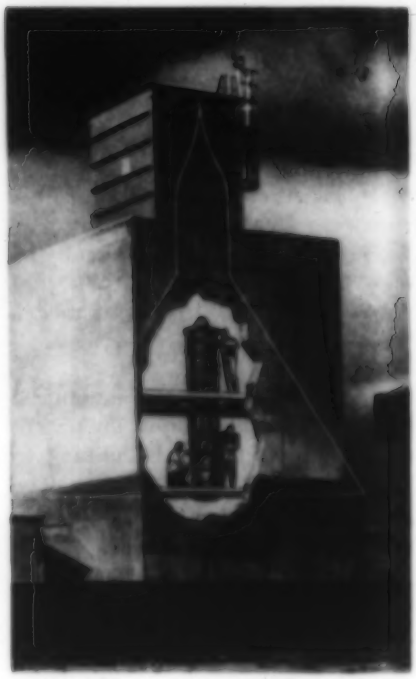
The Cambridge Wire Cloth Co.

WIRE CLOTH | METAL CONVEYOR BELTS | SPECIAL METAL FABRICATIONS

DEPARTMENT N, CAMBRIDGE 10, MARYLAND

OFFICES IN PRINCIPAL INDUSTRIAL CITIES

approval is not required as a condition of procurement of its radioisotopes. The company will produce, on request, any isotope which can be made with a cyclotron, and in addition, long-lived isotopes for which a demand exists will be stockpiled.



TEST CELL for testing jet engines in a vertical position has been built by Ryan Aeronautical Co. Experiments can be conducted on jet engines as they will operate in vertical-takeoff jet planes

Turret Lathe Tape Controlled

Full Automatic Operation Possible with Small Unit

CHICAGO, ILL.—Fully automatic operation of a Jones & Lamson turret lathe was demonstrated at the recent Machine Tool Show here. A compact control unit designed by Barnes Engineering Co. has been adapted to operate the lathe by signals from a plastic tape.

Distinguishing feature of the

unit is its small size and simple circuitry. This is possible, according to Barnes, because the operating principle is digital-to-analog. Most other systems operate in reverse. As a result, few vacuum tubes are required; most of the control is by simple telephone-type relays.

To set up the system for a particular operation, a process engineer first programs the entire operation step by step. These instructions are punched on the tape with the aid of a code book.

Signals from the punched tape control the movements of the lathe. Each signal is translated into a binary code number. There are 32 possible hole positions available for each machine operation.

In this lathe application, the control unit selects any one of 16 spindle speeds. It also operates turret indexing, cross slide indexing, coolant, hood, chuck and bar feed. All of the tool motions are completely tape controlled.

Lead screw accuracy is controlled to within 0.001-inch and cross slide motion to within 0.0005-inch. Pushbutton control and manual cranks are provided to jog the machine into position if desired.

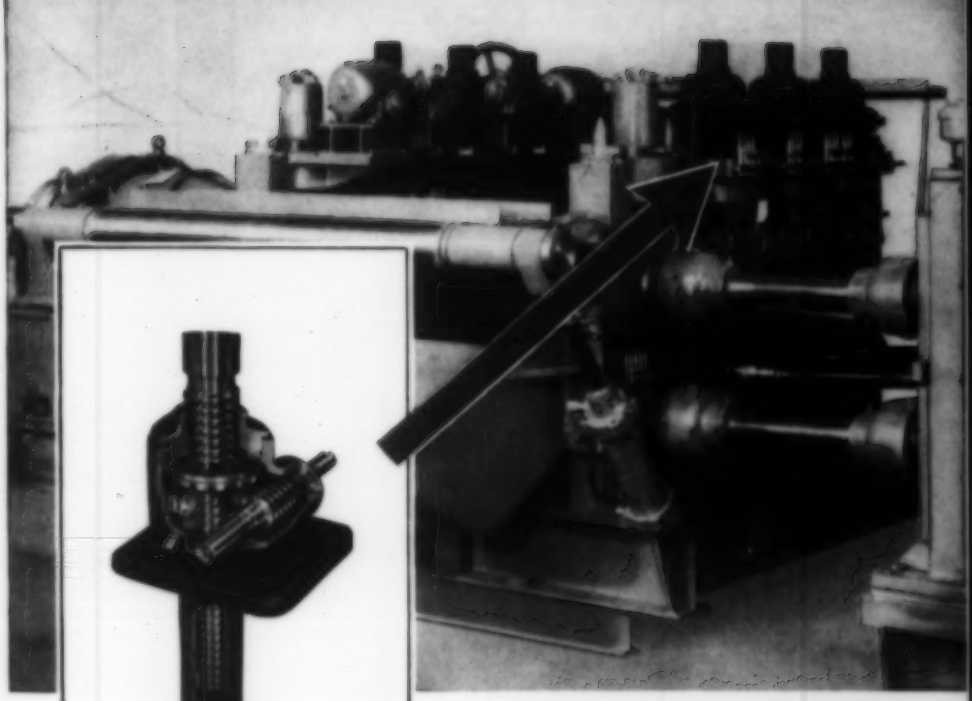
Michigan-Standard Alloy Casting Co. has been formed by consolidation of Standard Alloy Co., Cleveland, with Michigan Steel Casting Co., Detroit.

Barry Controls Inc. has acquired the **Insco Co.** of Groton, Mass. Insco is engaged in the development and manufacturing of electro-mechanical instruments and controls.

Meetings

AND EXPOSITIONS

Oct. 17-21—
National Metal Congress and Exposition to be held at Commercial
(*Continued on Page* 48)



Six Duff-Norton worm gear jacks (shown at left), connected by shafts controlled by electric motor, adjust leveling rolls on this leveler.

Here's a time-tested device for adjusting machinery

It's the Duff-Norton worm gear jack, successfully used by many machine builders as a component of equipment for precise, positive control of linear motion; applying pressure; resisting impact. Two or more of these jacks can be connected by means of shafting and mitre gear boxes or any power-operated positive control system, so that jacks always raise or lower under equal or unequal loads in perfect unison. Capacities range from 5 to 35 tons with any raise up to 25 inches; worm gear ratios, 8:1 to 45:1; turn of worm for each 1 inch raise, 10 to 180; available in either Acme or square threads. Screw ends and tops are available in many types and can be readily adapted to your specific requirements.

Duff-Norton worm gear jacks have been specified by America's leading designers and machinery builders for many years. They are made in 6 standard sizes or to your special order. Write for booklet!

DUFF-NORTON
Company

Duff-Norton Company
P. O. Box 1889, Pittsburgh 30, Pa.

Please send immediately a free copy of your Worm Gear Jack Booklet.

NAME _____ TITLE _____

COMPANY _____ PHONE _____

ADDRESS _____

BAKELITE

VINYL PLASTICS

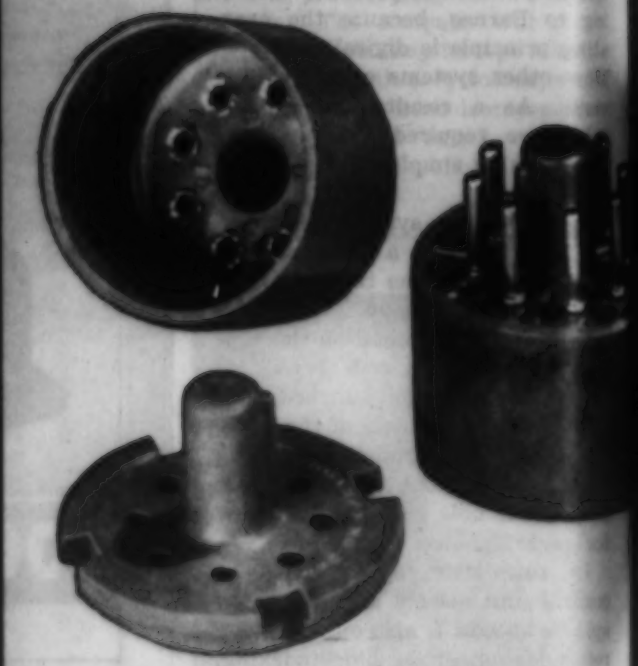
Road markers by
Plastic Engineering Inc., Cleveland 2, Ohio

This bright red molded road marker makes good use of the inherent toughness of BAKELITE Brand Vinyl Elastomeric Plastics. It's virtually immune to rough treatment. The color goes completely through, can't be scuffed off. The pyramid shape and the correct specific gravity of the plastic keep the marker in place when it's set over a freshly-painted traffic line.

BAKELITE Vinyl Elastomeric Plastics stay resilient even at below-zero temperatures. Their flexibility can be varied from semi-rigid to soft, depending on the amount of plasticizer used in their formulation. A wide range of colors is available. These materials are faithful to mold details and provide high surface gloss.

BAKELITE

PHENOLIC PLASTICS



Vacuum tube bases molded by
Sylvania Electric Products Company, Warren, Pa.

With its excellent high-frequency insulating characteristics, BAKELITE Brand "Low Loss" Phenolic BM-17748 is an ideal material for these molded vacuum tube bases. For example, its minimum dielectric strength is 325 volts/mil, while power factor ranges from 0.025 at 60 cycles down to 0.010 at 1,000,000 cycles. Consequently, this material is recommended for a wide range of electronics applications including coil forms, resistors, and capacitor housings.

BM-17748 is also more resistant to moisture and more dimensionally stable than most phenolic molding materials. It can be used not only where its outstanding electrical properties are paramount, but also in a variety of other applications where these additional service properties are useful.

BAKELITE

TRADE-MARK

GREATEST VARIETY, LARGEST RESOURCES FOR PLASTICS KEYED TO YOUR NEEDS

Your product, its sales and profits depend in great measure on the quality of the materials you specify. That's why so many molders and fabricators rely on Bakelite Company for their basic requirements.

At this one source you can select plastics with properties best suited to your product needs, because Bakelite Company offers the greatest variety of the large volume plastics.

In addition, Bakelite Company engineers—backed by over 45 years of plastics research—offer technical advice or assistance whenever you need it. If you have a problem in materials selection or processing, talk it over with the Bakelite Company sales representative nearest you. Or write Dept. JJ-108.

BAKELITE

POLYETHYLENE

PLASTICS

Instrument case molded by **Auburn Button Works, Inc.,** Auburn, N. Y., for Welch-Allyn, Inc., Skaneateles Falls, N. Y.

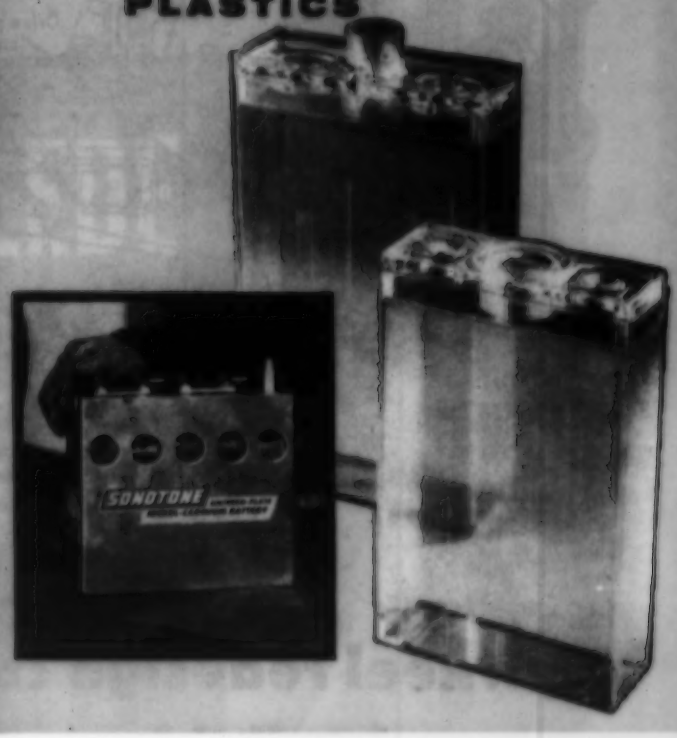
Cleverly designed, this entire case for diagnostic instruments is one-piece molded of BAKELITE Brand Polyethylene. Compartments, hinge, flaps, and the simulated alligator surface were all formed in a single operation. In service, the resilient polyethylene makes the case shock-proof and virtually indestructible. It can be sterilized in standard germicides; polyethylene is inert to most chemicals.

Although lightest of all commercial plastics, BAKELITE Polyethylene provides husky construction. It's tough and flexible, even at −70 degrees F. Other advantages include outstanding dielectric properties, making it an especially important extrusion material for wire and cable construction.

BAKELITE

C-11

PLASTICS



Cell cases molded by **Plastic Mold and Engineering Co.,** Providence, R. I. for Sonotone Corp., Elmsford, N. Y.

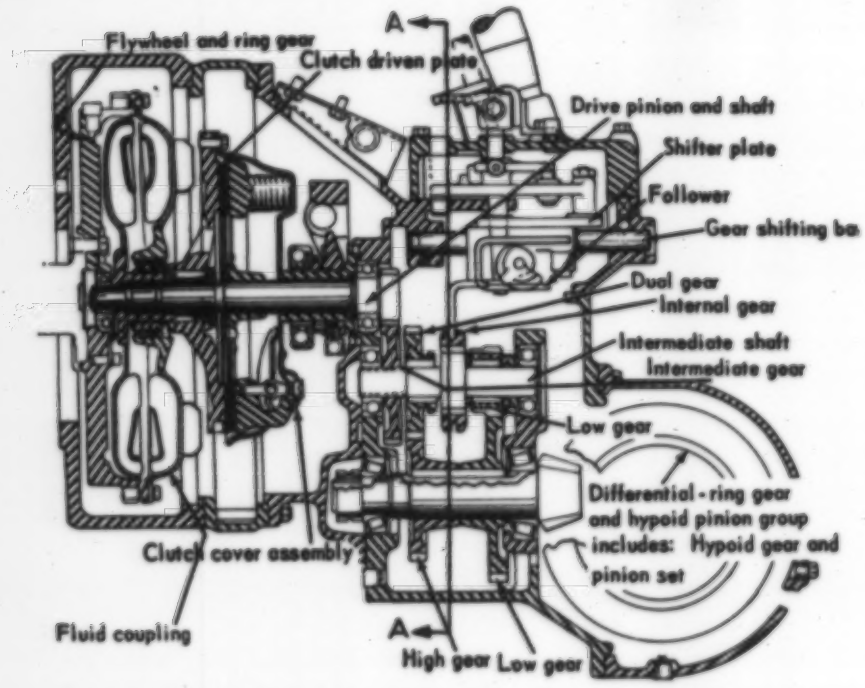
These battery cell cases, molded of BAKELITE Brand C-11 Plastic, are designed to give many years of service, according to the manufacturer. The plastic, an acrylonitrile-styrene copolymer, is so chemical-resistant that it withstands contact with highly corrosive electrolyte—a 30%-by-weight solution of potassium hydroxide in distilled water. It's so tough that a "shake test" shows it can take stresses as high as 500 cycles at 15 G's.

BAKELITE C-11 Plastic is also used for the cover, which is cemented to the case, making the cell a sealed unit with the sole exception of the vent plug. The high degree of transparency found in C-11 Plastic permits visual inspection at all stages of the battery's manufacture.

BAKELITE
BRAND
PLASTICS

PHENOLICS • STYRENES • IMPACT STYRENES
POLYETHYLENES • VINYLS • POLYESTERS
EPOXIES

BAKELITE COMPANY, *A Division of Union Carbide and Carbon Corporation* UCC 30 East 42nd Street, New York 17, N.Y.
In Canada: Bakelite Company, Division of Union Carbide Canada Limited, Belleville, Ontario
The term BAKELITE and the Trefoil Symbol are registered trade-marks of UCC

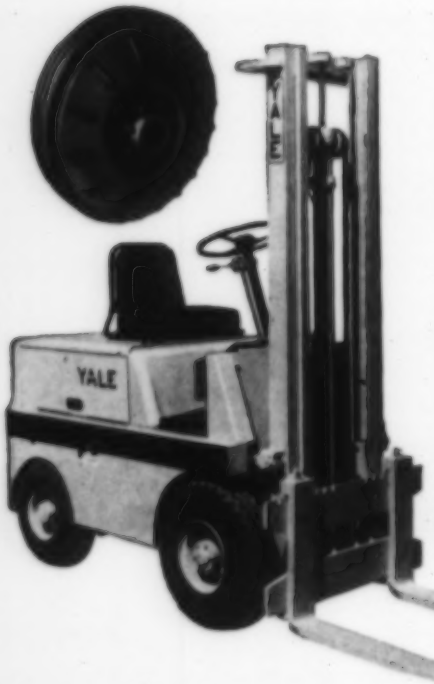


Flywheel redesign conserves space for fluid coupling...

Twin Disc's Fluid Coupling, *mounted compactly within the flywheel,* solved the space problem, reduced clutch maintenance and increased maneuverability of Yale's new G-52 Gasoline Fork Truck.

Materials handling trucks must make many rapid reversals of direction, numerous short runs at high acceleration, smooth starts and stops that won't cause load shifting . . . obviously a fluid coupling job. But, in an already tight arrangement, nesting the coupling *inside the flywheel* was the only solution without increasing truck length.

Next time *you're* planning or designing equipment that requires the power-smoothing, shock-absorbing advantages of Twin Disc Fluid Couplings . . . particularly where overall space and weight limitations present tough obstacles . . . contact Twin Disc Clutch Company, Hydraulic Division, Rockford, Illinois.



Twin Disc 12.25 Fluid Coupling smooths out operations on Yale's new G-52 line of Gasoline Fork Lift Trucks.

TWIN DISC

TWIN DISC

Fluid Couplings

News Roundup

(*Continued from Page 45*)

Museum and Convention Halls, Philadelphia, Pa. Sponsored by the American Society for Metals. Additional information may be obtained from society headquarters, 7301 Euclid Ave., Cleveland 3, O.

Oct. 19-21—

Gray Iron Founders' Society. Annual Meeting to be held at Hotel Schroeder, Milwaukee, Wis. Additional information may be obtained from society headquarters, National City-East Sixth Bldg., Cleveland 14, O.

Oct. 23-26—

American Gear Manufacturers Association. Semiannual Meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, One Thomas Circle, Washington 5, D. C.

Oct. 24-25—

Steel Founders' Society of America. Fall Meeting to be held at The Greenbrier, White Sulphur Springs, W. Va. Secretary is George K. Dreher, 606 Terminal Tower, Cleveland 13, O.

Oct. 24-26—

American Standards Association. Thirty-seventh Annual Meeting in conjunction with the Sixth National Conference on Standards to be held at the Sheraton-Park Hotel, Washington, D. C. Sponsored by ASA and the National Bureau of Standards. Additional information may be obtained from society headquarters, 70 East 45th St., New York 17, N. Y.

Oct. 25-27—

American Institute of Electrical Engineers. Aircraft Electrical Equipment Conference to be held at the Hollywood Roosevelt Hotel, Los Angeles, Calif. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

Oct. 27-28—

National Conference on Industrial Hydraulics. Eleventh Annu-

al Meeting to be held at the La-Salle Hotel, Chicago, Ill. Sponsored by the Illinois Institute of Technology and Armour Research Foundation in co-operation with engineering societies and industrial organizations. Additional information may be obtained from C. A. Arents, Secretary, Illinois Institute of Technology, Technology Center, Chicago 16, Ill.

Oct. 31-Nov. 1—

Magnesium Association. Annual meeting to be held at the Biltmore Hotel, New York, N. Y. Additional information may be obtained from society headquarters, 122 East 42nd St., New York 17, N. Y.

Oct. 31-Nov. 1—

Scientific Conference on Solar Energy to be held at the University of Arizona, Tucson, Arizona. Additional information may be obtained from the Public Relations Dept., Stanford Research Institute, Stanford, Calif.

Nov. 1-5—

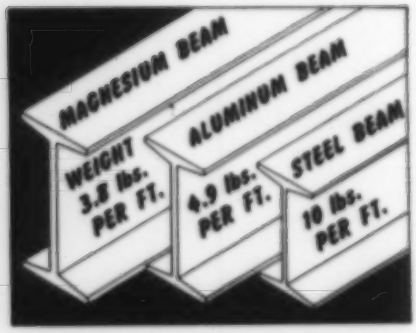
World Symposium on Applied Solar Energy to be held at the Westward Ho Hotel, Phoenix, Arizona. Sponsored by Stanford Research Institute, the Association for Applied Solar Energy and the University of Arizona. Additional information may be obtained from the Public Relations Dept., Stanford Research Institute, Stanford, Calif.

Oct. 31-Nov. 2—

Society of Automotive Engineers. Transportation Meeting to be held at The Chase Hotel, St. Louis, Mo. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Nov. 1-3—

Investment Casting Institute. Fall Meeting to be held at the Sheraton-Cadillac Hotel, Detroit, Mich. Additional information may be obtained from society headquarters, 27 East Monroe St., Chicago 3, Ill.



THESE BEAMS ARE OF EQUAL STIFFNESS. Relative Stiffness in Bending, based on rectangular beams of constant width and equal weight: STEEL 1.0; ALUMINUM 8.9; MAGNESIUM 18.9.

Maximum stiffness with minimum weight

Of all structural metals, magnesium has the highest stiffness-to-weight ratio.

Modulus of elasticity for magnesium is 6.5 million pounds per square inch; for aluminum 10 million; and for steel 29 million. Stiffness is resistance of a material to deflection under a given load within the elastic limit. The amount of such deflection is proportional to the amount of inertia of the beam multiplied by the elasticity modulus of the material.

When a part previously of steel or aluminum is being redesigned for magnesium, the moment of inertia must be increased in proportion to the lower elastic modulus of magnesium to obtain the same stiffness. But – the moment of inertia increases as the cube of the thickness of the beam. So—very little added thickness tremendously increases stiffness. The net result is a slightly thicker section for the magnesium part, and a marked reduction in weight.

This is why magnesium is used for floor beams in airplanes; for radar feed horns and reflectors where low inertia and high stiffness are required; and for hundreds of other similar applications.

B&P engineers will help you redesign in magnesium. B&P offers the magnesium industry's most complete facilities for fabrication and assembly. Your inquiry will bring a descriptive booklet.

BROOKS & PERKINS, INC.

1940 West Fort Street
Detroit 16, Mich.

Engineering News Roundup

Nov. 2-4—

National Fluid Power Association. Fall Meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. Additional information may be obtained from Barrett Rogers, Executive Secretary, 1618 Orrington Ave., Evanston, Ill.

Nov. 2-4—

Society of Automotive Engineers. Diesel Engine Meeting to be held at The Chase Hotel, St. Louis, Mo. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Nov. 9-10—

Society of Automotive Engineers. Fuels and Lubricants Meeting to be held at The Bellevue-Stratford, Philadelphia, Pa. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Nov. 13-18—

American Society of Mechanical Engineers. Diamond Jubilee Annual Meeting to be held at Hotel Congress, Chicago, Ill. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Nov. 14-18—

Chicago Exposition of Power & Mechanical Engineering to be held at the Chicago Coliseum. Under the auspices of the ASME as part of the Diamond Jubilee Meeting. Additional information may be obtained from E. K. Stearns, Exposition Manager, International Exposition Co., 480 Lexington Ave., New York 17, N. Y.

Nov. 14-17—

Second International Automation Exposition to be held at the Navy Pier, Chicago, Ill. Additional information may be obtained from Richard Rimbach Associates, 845 Ridge Ave., Pittsburgh 12, Pa.

Nov. 16-18—

Society for Experimental Stress Analysis. Annual Meeting to be held at Hotel Sheraton, Chicago, Ill. Additional information may be obtained from Dr. W. M. Murray, Secretary-Treasurer, P.O. Box 168, Cambridge 39, Mass.

Nov. 17-18—

American Society for Quality Control. Tenth Mid-West Conference to be held at Hotel Schroeder, Milwaukee 1, Wis. Additional information may be obtained from P.O. Box 1204, Milwaukee 1, Wis.

Dec. 11-14—

American Society of Agricultural Engineers. Winter Meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. Additional information may be obtained from Frank B. Lanham, Secretary, St. Joseph, Mich.

Dec. 10-16—

International Atomic Exposition to be held at the Public Auditorium, Cleveland, O. Sponsored by the American Institute of Chemical Engineers. Additional information may be obtained from Athel F. Denham, Director, 931 Book Bldg., Detroit 26, Mich.

Dec. 12-16—

Nuclear Engineering & Science Congress to be held at the Public Auditorium, Cleveland, O. Additional information may be obtained from the Engineers Joint Council, 29 West 39th St., New York 18, N. Y.

Jan. 9-13, 1956—

Society of Automotive Engineers. Annual Meeting to be held at the Sheraton-Cadillac Hotel and Hotel Statler, Detroit, Mich. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

May 24-25—

Third Conference on Mechanisms to be held at Purdue University, West Lafayette, Ind., sponsored by the Purdue School of Mechanical Engineering and MACHINE DESIGN. Additional information may be obtained from the Editor, MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

MEN
OF MACHINES

The Lux Clock Mfg. Co., Waterbury, Conn., has announced the appointment of **George Cagen** as chief product engineer. Mr. Cagen, a graduate of Worcester Polytechnic Institute, previously served as chief engineer with both Jaeger Watch Co. and Self Winding Clock Co.

Hamilton F. Biggar Jr. has been named manager of new product development by Reliance Electric & Engineering Co., Cleveland. This appointment combines the atomic power motor development activity, which Mr. Biggar has been managing, with the research and technical services of the engineering department. **Robert R. Hayes** has been named supervisor of the atomic power department. Mr. Hayes has had several years of experience in the design of large and small motors at Reliance, and he co-ordinated the introduction of dc motors at the company's Canadian subsidiary.

H. J. Buttner

H. J. Buttner has been appointed manager of engineering by the Le Roi Div. of Westinghouse Air Brake Co., Milwaukee. For nearly 25 years Mr. Buttner has been concerned with the design and development of high-output internal combustion engines, including all phases of research, development and testing. Shortly after receiving a B.S. degree in mechanical engineering from Purdue University in 1931 he joined the Allison Div. of General Motors Corp., progressing from an assistant project engineer to chief test engineer. Subsequently he was named chief power plant engineer of the Aircraft Development Section of the Fisher Body Div. of General Motors. In 1944 Mr. Buttner joined the Aircraft Engine Div. of Packard Motor Car Co. as chief development engineer. In 1946 he received his master's degree from Purdue and was appointed professor of automotive engineering. He taught there until 1952, when he joined Continental Motor Corp., where he was first assistant director, then director, and finally manager of the contract division. During the last year Mr. Buttner has been engaged in a U. S. Army Ordnance project.

The appointment of **John C. Lee** as chief engineer was announced recently by the industrial division of Wayne Pump Co., Philadelphia. For the last seven years Dr. Lee has been associated with Armour Research Foundation of the Illinois Institute of Technology, in charge of the hydraulic power equipment section and heat power research department.

Formerly a consulting engineer in Fort Wayne, Ind., **H. E. Rittenhouse** has been named chief engineer of the Pittsburgh Div. of Rockwell Mfg. Co. Mr. Ritten-

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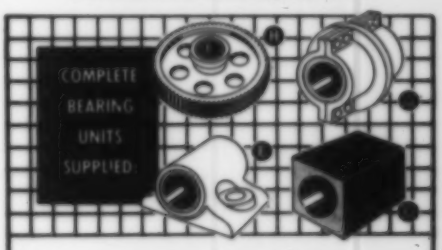

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Men of Machines

house succeeds **Paul Mankin,** who was promoted to general manager of the division early this year. **Howard C. Gebhart** was named chief engineer of the company's Delta Power Tool Div. at Bellefontaine, O. He was formerly chief engineer of Kett Tool Co.

The promotion of **David B. Parkinson** to vice president has been announced by Brush Electronics Co., Cleveland. Dr. Parkinson, who is general engineering manager, has responsibility for all design and production engineering at the company. He joined Brush in 1948.

Harry L. Owens has joined Texas Instruments Inc., Dallas, Tex., as chief engineer of the Semiconductor Products Div. Previously, he was chief of the Solid State Devices branch at the Signal Corps Engineering Laboratories, Fort Monmouth, N. J. In his new position Mr. Owens will be responsible for the development and engineering of germanium and silicon semiconductor products.

Crusher Engineering Div. of Poor & Co., Philadelphia, has named **Forest Neely** director of development and **John Kessler Jr.** chief engineer. Mr. Neely was formerly director of engineering. Immediately prior to joining the staff of this new Poor & Co. division he was employed by Pennsylvania

Forest Neely

John Kessler Jr.

Crusher Co. Other associations have included Patterson Foundry and Machine Co., Celanese Corp., Blaw-Knox Co., Alpha Portland Cement Co., and Consolidation Coal Co. Mr. Neely is a graduate of the University of West Virginia in mechanical and mining engineering.

Mr. Kessler served on the engineering department staff of Pennsylvania Crusher Co. since 1938. He has had wide experience in the engineering and design of crushing machinery. Mr. Kessler is a mechanical engineering graduate of Rutgers University.

Hammel-Dahl Co., Providence, R. I., has announced the election of **John R. Curran** to vice president. Mr. Curran joined the company in 1945 as design engineer, was appointed chief design engineer four years later, and was made director of engineering in 1953.

Appointment of **Joseph J. Eachus** as systems director and **J. Ernest Smith** as director of engineering was announced recently by Datamatic Corp., Newton Highlands, Mass. Dr. Eachus, a former member of the faculty of Purdue University, has been engaged in research and development work for the Department of Defense. Mr. Smith was formerly assistant vice president and director of en-

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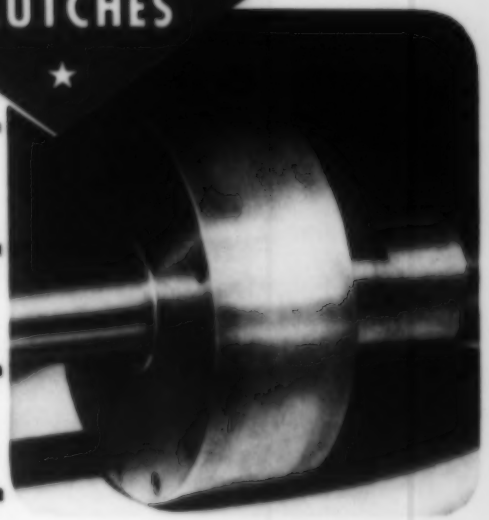

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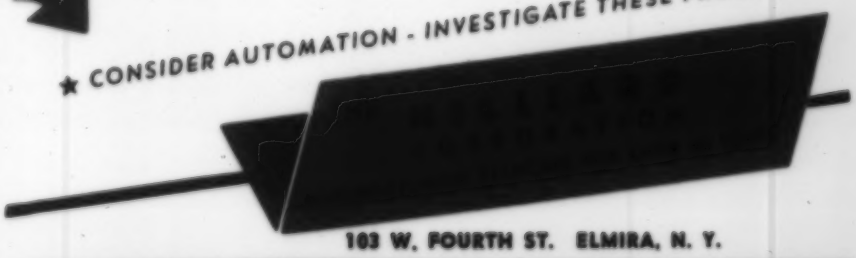

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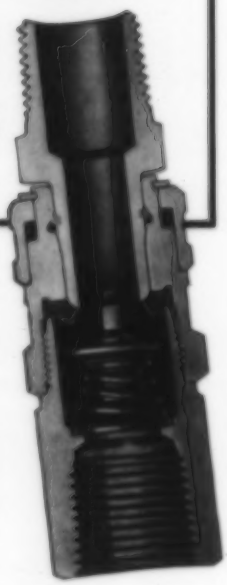

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- Positive locking.
- Equipped with automatic sleeve lock.

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Men of Machines

gineering for Raytheon Mfg. Co. The newly formed Datamatic Corp., owned jointly by Minneapolis-Honeywell Regulator Co. and Raytheon, is engaged in the development and production of large, high-speed data processing equipment.

Ramo-Wooldridge Corp., Los Angeles, recently announced several appointments to the staff of its Guided Missile Research Div. **Louis G. Dunn**, formerly associate director, has been named director of the division. **Edward B. Doll** joined the division as director of the project control staff; **Allen F. Donovan** is director of the aeromechanics and propulsion staff; and **Edward R. Toporeck** is director of the field test and instrumentation staff.

Announcement has been made by the newly established Harrison, N. J., division of Worthington Corp. of the promotion of several members of the engineering staff. **William C. Osborne** has been named assistant to the manager of engineering. **Norman L. Meyerson** is manager and **Charles A. Macaluso** is assistant manager of the research and development division.

Progressive Welder Sales Co., Detroit, has appointed **Ronald L. Loup** to the position of director of the development engineering division.

Frank Breckenridge has been named vice president in charge of engineering and manufacturing for the three plants of Globe Hoist Co. at Philadelphia, Des Moines, Iowa, and Long Beach, Calif.

David Albert Huffman, assistant professor of electrical engineering at Massachusetts Institute of Technology, will be awarded the Louis E. Levy Medal of the Franklin Institute of the State of Pennsylvania at the Institute's Annual Medal Day ceremonies, October 19. The medal will be awarded in recognition of Dr. Huffman's paper, "The Synthesis of Sequential Switching Circuits," which ap-

peared in the March and April 1954 issues of the *Journal of the Franklin Institute.*

Robert S. Reaves has been named assistant to the vice president and director of engineering of the tractor group by Allis-Chalmers Mfg. Co., Milwaukee. Mr. Reaves joined the company as a student engineer in 1935.

Daniel Mapes, a vice president of Walter Kidde & Co. Inc., Belleville, N. J., has been named to head the Engineering and Research Div., one of five divisions created in the recent reorganization of the firm.

Appointment of **Sheldon G. Little** as an assistant chief engineer has been announced by General Motors Corp. Truck & Coach Div., Pontiac, Mich. Mr. Little formerly was engineer for the GM Styling Section. He joined the engineering staff of the Cadillac Motor Div. in 1929, as a GM Institute student, was later affiliated with the Cleveland Tank Plant, and transferred to the Styling Section last year.

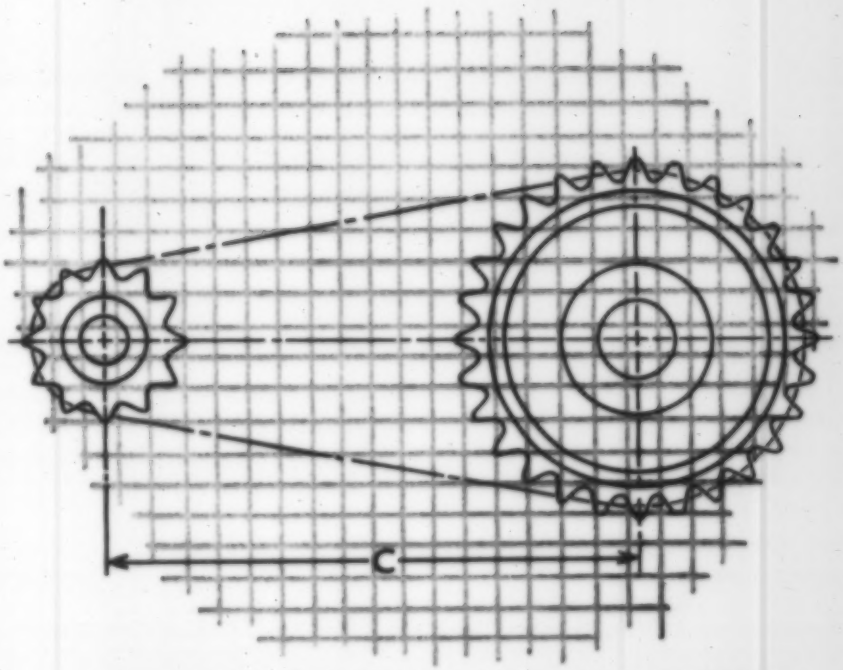
B. L. Waddell recently joined the Datex Div. of G. M. Giannini & Co. Inc., Pasadena, Calif., as senior systems development engineer.

George J. Basl has been named product design engineer for Viking Air Conditioning Div. of National-U. S. Radiator Corp. in Cleveland.

The American Nuclear Society, pioneer professional organization of scientists and engineers engaged full-time in industrial governmental and educational aspects of atomic energy, has announced the election of **W. H. Zinn** as its first president. Dr. Zinn is director of the U. S. Atomic Energy Commission's Argonne National Laboratory, Lemont, Ill.

Robert W. Phillips recently was appointed chief engineer of the Flex-O-Tube Div. of Meridan Corp., Inkster, Mich. He was chief engineer of the Weatherhead Co.

Designers! Determine this Chain Length



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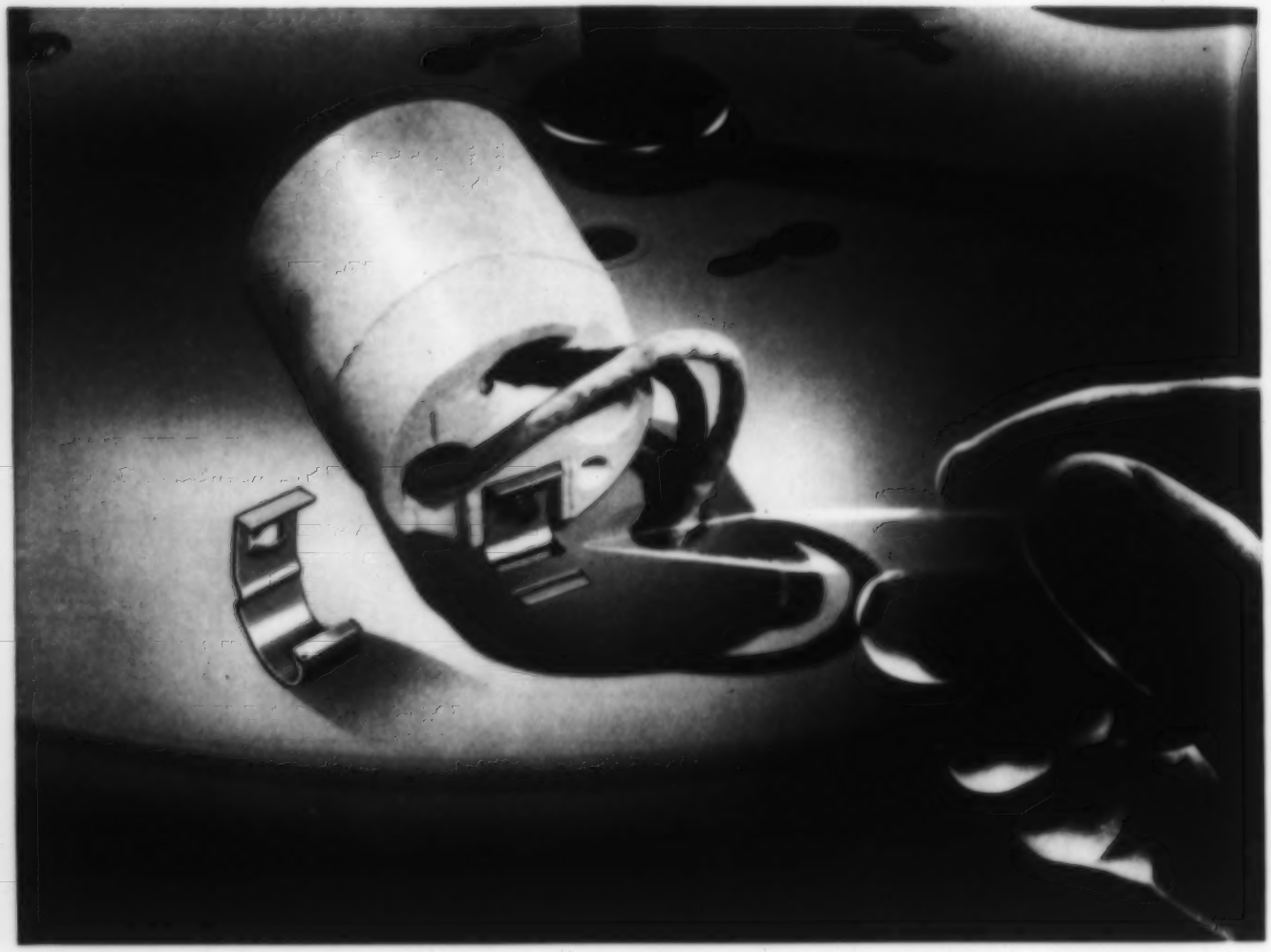

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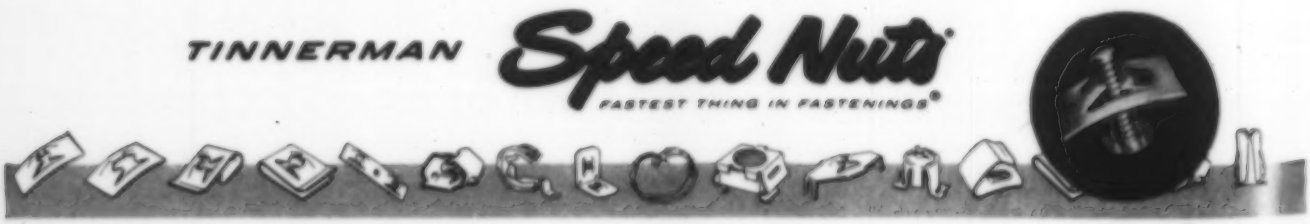


MACHINE DESIGN
OCTOBER 1955

A Step Toward Professional Unity

HOW BIG is the engineering profession? Strangely enough, nobody knows for sure. More than half a million persons told the 1950 census takers that they were engineers. But only 190,000 are registered as professional engineers with their states.

Most authorities believe the half-million figure is away too high. Why? Because there is no universally accepted definition of an engineer, it is thought that many men, or their wives, upgraded themselves in describing their occupations to the census takers. Additionally, attempts to put together authentic unduplicated figures on engineering registration, professional society memberships, and so forth, fail to come up with any such total as half a million.

On the other hand, the census figures on doctors, dentists and lawyers, even architects and surveyors, can be checked with reasonable accuracy because state registration is well-nigh universal for these occupations.

But because registration is not required of most of those practicing engineering as employees of industry, the engineering registration figures do not accurately reflect the size or complexion of the engineering profession as a whole. Consulting engineers and engineers employed on public works generally must be registered, and the engineering registration rolls therefore are strongly flavored with those particular branches of the profession.

In striving toward professional unity and recognition, many engineers in industry appear to be overlooking this ready-made means of establishing status and bringing all engineers together.

While registration of itself provides no means for collective action, it is a prerequisite for membership in the National Society of Professional Engineers, with its affiliated state and local societies. These groups can act for the profession, and their influence would be vastly enhanced if it could be said that they truly represent a big majority of engineers—including those employed in industry.

Elsewhere in this issue, John D. Constance lifts the veil of mystery from registration and shows how any engineer competent to do his job can, with a little effort and at no great expense, become registered as a professional engineer.

If there are indeed half a million engineers in this country, our profession could exert a powerful combined influence which at present is too dissipated to be effective. It could be made effective if, as a first step, every individual calling himself an engineer would see to it that he is officially recorded as such.

Colin Carmichael

EDITOR

How to Obtain a Professional Engineer's

A short guide to requirements, necessary procedures, and information needed for licensing as a registered professional engineer

By John D. Constance
Consulting Engineer
Cliffside Park, N. J.

ALL states, the District of Columbia and territorial possessions have enacted registration laws regulating the practice of engineering. These laws established minimum qualifications of education and experience required for all who would practice or offer to practice professional engineering.

Advantages of such registration to the individual engineer, his company, and the public are many.

Registration creates a definite recognition of the professional status of engineering, and also requires a higher standard of engineering. It is giving the engineering profession a higher public status, which has been lacking in the past. Registration does not organize for anything, but it does have a tendency to make engineers think of themselves as a unified group.

Registration helps improve the quality of engineering. Although registration does not classify a man as to his ability to do a job, it has introduced a minimum standard which assures that practicing engineers are qualified in their respective fields.

One of the most outstanding effects of engineering registration is the legal status it gives engineering. A number of court cases show that a contract to do engineering work is not a legal contract unless the engineer is registered. Thus, any fee cannot legally be collected.

Manufacturers may find it advantageous to have registered engineers in their employ. If, for example, an airplane had a design defect, and injury or death should occur as a direct result, criminal negligence could possibly be charged unless registered engineers were in charge of design. This could be true of electrical appliances, automobiles and many other devices in common use.

Requirements for Engineering Registration

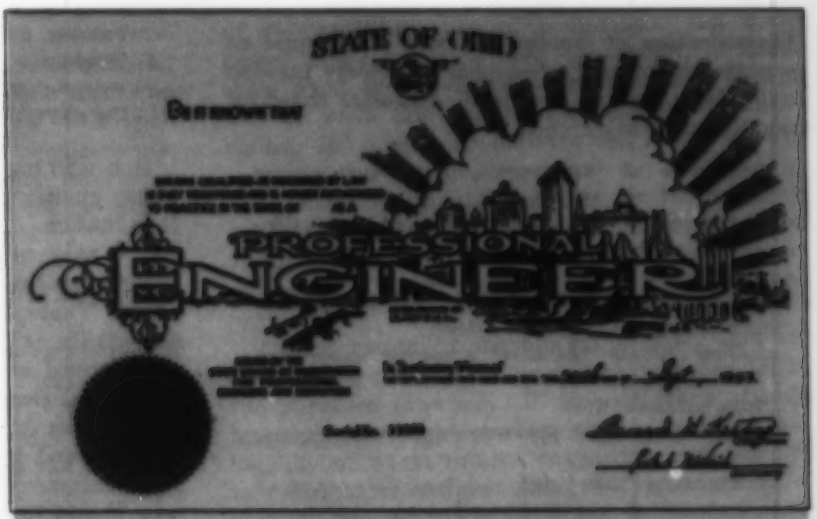
Requirements for registration are fundamental, and the various states adhere closely to the so-called "Model Law." Registration is basically and legally for the protection of the public, and all state registration laws have a provision to this effect. The wording in most of the laws is similar to that of the Model Law and probably the most significant is the following, quoted from the Act of Congress of the United States regulating the practice of engineering in the District of Columbia:

In order to safeguard life, health and property and promote the public welfare, the practice of engineering . . . is hereby declared to be subject to regulation in the public interest. It is further declared to be a matter of public interest and concern that the profession of engineering merit and receive the confidence of the public and that only qualified persons be permitted to engage in the practice of engineering. All provisions of this Act relating to the practice of engineering shall be construed in accordance with this declaration of policy. Any person engaged in or offering to engage in the practice of engineering . . . shall submit evidence that he is qualified to practice and shall be registered . . . .

The Model Law has three alternate standard requirements:

1. **Graduation from an approved engineering cur-**

License



Why Become a Registered Professional Engineer?

Each year, more and more engineers become "registered professional engineers." Why? What do they gain? Here are a few of the advantages:

- ***Improved Professional Status:*** **Engineering registration is evidence of ability, and certification of individual competence according to recognized standards.**
- ***Job Advancement Possibilities:*** **Many engineers find that their companies recognize and reward the achievement of professional engineer status.**
- ***Defined Legal Status:*** **In court cases the fact that registered engineers are in charge of the project can mean the difference between winning or losing the case. A contract to do engineering work is not legal unless the engineer is registered. Also, only registered engineers can testify as engineering expert witnesses.**
- ***Improvement of the Profession:*** **Engineering registration tends to unify engineers on a professional level, sets a minimum standard, and increases public recognition of the professional standing of engineering.**

What are the requirements to become a registered professional engineer, and what steps are necessary? The answers are outlined in this article.

riculum plus four years or more of experience in engineering work of a character satisfactory to the board.

2. If a man is not an engineering college graduate, **eight years or more of engineering work** of a character and nature approved by the board, **plus a written examination.** The written examination is to show that the man has acquired his education in some way other than in college.

3. **Twelve years or more of lawful practice in engineering work** of a satisfactory character, indicating that the applicant is competent to practice engineering, and provided further that the applicant is no younger than 35 years. This requirement is for the man of long-established practice. Most states now require all applicants to pass a written examination, except those men with recognized standing and long experience.

Acceptable Engineering Experience: Engineering experience must be of a grade and character satisfactory to the board of examiners. **The acceptable amount is often less than the time elapsed after graduation.** The number of calendar years of experience does not necessarily equal the same number of years of satisfactory "approved" experience.

Acceptable engineering experience is something that defies exact definition. However, it is predicated on a knowledge of engineering mathematics, physical and applied sciences, properties of materials, and the fundamental principles of engineering design. Most boards insist that this experience be broad in scope and of such nature as

to develop and mature the applicant's knowledge and judgment.

Classification of Applicants: Men who aspire to the possession of a Professional Engineers License usually fall into one of several categories based on education and experience:

1. Graduates of "approved" engineering schools with:
   a. Less than four years (approved, not calendar) of engineering experience after graduation.
   b. Four "approved" years or more of such experience but less than fifteen.
   c. Over fifteen years of approved experience after graduation.
2. Nongraduates with:
   a. Less than eight years of "approved" experience.
   b. Eight or more (but not less than twelve) "approved" years of engineering experience.
   c. Twelve or more "approved" years of engineering experience.
3. Nongraduates with partial educational credit from approved engineering schools and with a number of "approved" years of experience.
4. Graduates of nonapproved engineering schools with a number of years of "approved" engineering experience.

Men who meet the requirements of 1a, 2b, 3 and 4 may qualify for the Engineer-in-Training (E.I.T.) examination. Those under classification 1b, 2c, 3 and 4 may qualify for the full examination and achieve professional status as determined by the board. Those classified under 2a, 3 and 4 may not qualify as determined by the board on the basis of approved engineering experience to fulfill minimum legal requirements.

A number of aspirants who fit into classifications 1c, 2c, 3 and 4 may meet special requirements and upon recommendation of the board of examiners may obtain licensure without written examination. This is known as licensure by endorsement.

Where To Get Information on Professional Engineering Registration

If you live in . . .	Write to State Board of Engineering Examiners, care of . . .
Alabama	Clifton C. Cobb, executive secretary, 609 Monroe St., Montgomery
Alaska	Linn A. Forrest, secretary, Box 251, Juneau
Arizona	Mrs. Rayma Neeb, executive secretary, Room 319, Arizona Title Bldg., 128 N. 1st. St., Phoenix
Arkansas	V. E. Scott, secretary, Box 175 Pulaski Hts. Station, Little Rock
California	William A. White, executive secretary, 529 Business & Professional Bldg., Sacramento
Colorado	M. E. Langsteiner, asst. secretary, 20 Capitol Bldg., Denver
Connecticut	William K. Simpson, secretary, 30 Oak St., Hartford 6
Delaware	Carmen J. Facciolo, secretary, 2808 N. Van Buren St., Wilmington
District of Columbia	Mrs. Lacey W. Coad, asst. secretary, 1740 Massachusetts Ave., N. W., Washington 6
Florida	Mrs. Ann P. Clover, executive secretary, 408 John F. Seagle Bldg., Gainesville
Georgia	R. C. Coleman, joint secretary, 111 State Capitol, Atlanta
Hawaii	Wm. C. Furer, asst. secretary, 1909 Aleo Place, Honolulu 14
Idaho	S. M. Barton, asst. secretary, 623½ Main St., Boise
Illinois	Fedric B. Selcke, supt. of registration, State House, Springfield
Indiana	Ferdinand Jehle, secretary, 230 State Capitol, Indianapolis
Iowa	W. G. Cunningham, secretary, State Capitol Bldg., Des Moines
Kansas	Mrs. Della Serrett, executive secretary, 422 Garlinghouse Bldg., Topeka
Kentucky	C. S. Crouse, secretary, c/o Univ. of Kentucky, Lexington
Louisiana	F. W. Macdonald, executive secretary, Room 233, Civil Engineering Bldg., Tulane Univ., New Orleans 18
Maine	Bryant L. Hopkins, secretary, Box 103, Waterville
Maryland	J. W. Gore, secretary, 1101 Key Highway, Baltimore 30
Massachusetts	Mrs. Gertrude J. Cammon, secretary, Room 34, State House, Boston
Michigan	Henry G. Groehn, executive secretary, 705 Cadillac Square Bldg., Detroit 26
Minnesota	Helen D. Carlson, executive secretary, 316 New York Bldg., St. Paul 1
Mississippi	O. B. Curtis Sr., seecretary, P.O. Box 3, Jackson
Missouri	Mrs. Clemie V. Wall, secretary, Box 184, Jefferson City
Montana	E. R. Dodge, secretary, 419 West Cleveland, Bozeman
Nebraska	Roy M. Green, secretary, 210 Ferguson Hall, Univ. of Nebraska, Lincoln 8
Nevada	Stanley G. Palmer, secretary, c/o College of Engineering, Univ. of Nevada, Reno
New Hampshire	Henry T. Spear, acting secretary, P.O. Box 235, Laconia
New Jersey	Thomas E. Heathcote, secretary-director, 921 Bergen Ave., Jersey City 6
New Mexico	John R. Erickson, secretary, P.O. Box 1079, Santa Fe
New York	Newell L. Freeman, secretary, 23 South Pearl St., Albany
North Carolina	Robert B. Rice, secretary, c/o Dept. of Diesel Engineering, N. C. State College, Raleigh
North Dakota	A. L. Bavone, secretary, P.O. Box 1265, Minot
Ohio	Robert N. Waid, secretary, 21 West Broad St., Columbus 15
Oklahoma	Gwynne B. Hill, secretary, 2901 Classen Blvd., Oklahoma City 6
Oregon	E. A. Buckhorn, secretary, 717 Board of Trade Bldg., Portland
Pennsylvania	Miss Rebecca J. Nickles, secretary, 324 Education Bldg., Harrisburg
Puerto Rico	Joaquin Mercado-Cruz, secretary-treasurer, P.O. Box 9156, Santurce
Rhode Island	Philip S. Mancini, secretary, 218 State Office Bldg., Providence
South Carolina	T. Keith Legare, secretary, P.O. Drawer 1404, Columbia
South Dakota	Earl E. Dake, secretary, c/o S. Dakota School of Mines & Technology, Rapid City
Tennessee	Granbery Jackson, Jr., secretary-treasurer, 503 Nashville Trust Bldg., Nashville 3
Texas	Carl L. Svensen, exec. secretary, 308 W. 15th St., Austin 1
Utah	Frank E. Lees, director, 324 State Capitol Bldg., Salt Lake City
Vermont	Walter D. Emerson, secretary, c/o Norwich Univ., Northfield
Virginia	Turner N. Burton, secretary, P.O. Box 1-X, Richmond
Washington	Edw. C. Dohm, secretary, Dept. of Licenses, Professional Div., Transportation Bldg., Olympia
West Virginia	Robert Williamson Jr., secretary, 301 Morrison Bldg., Charleston
Wisconsin	W. A. Piper, secretary, 1140 State Office Bldg., Madison 2
Wyoming	Mrs. Wilma H. Lang, asst. secretary, 201 State Capitol Bldg., Cheyenne

How to Apply for Registration

Application is a straightforward procedure. Write to the person listed in the accompanying table. Request a copy of the registration form and the state registration act. The law will spell out the specific age and experience requirements. Fill out all forms, obtain the necessary references and return the form as directed with the statutory fee, ranging from $15 to $25.

Proving Engineering Experience: The application form provides space for writing in the experience record of the applicant. **This experience record is the most important part of the form, but the least understood.**

The matter of "acceptable" experience is all too often given merely passing attention. As a result, this vital information is not well documented and loses much of its effect. Nevertheless, in evaluating a man's experience **the board must reach its decision by what is written in the application.** It cannot read in between the lines and cannot go by mere hearsay.

The application is no place for modesty. It is not enough to list job titles, no matter how impressive. The record must show the complete story and must describe the applicant's functions in detail, leaving no doubt on the part of the board as to the nature and value of the man's experience.

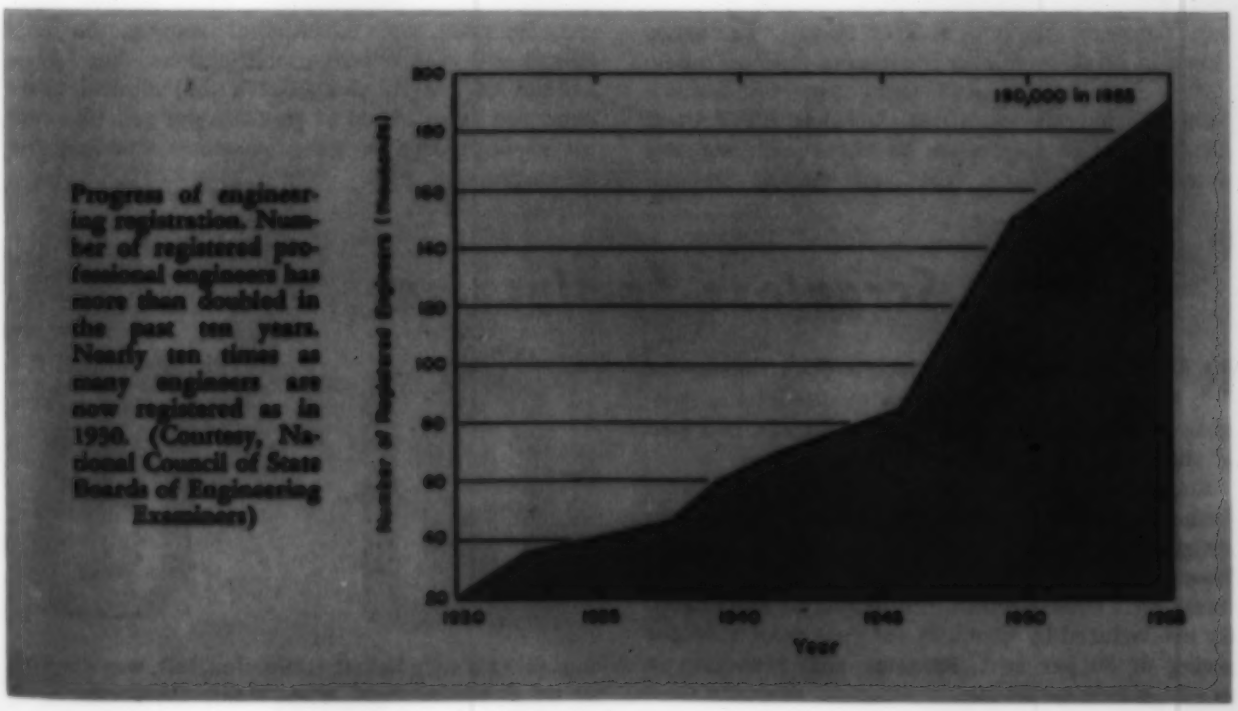
In submitting the amplified record of practical experience, **the applicant must be sure to define responsibilities clearly** in different organizations. These are best shown by specific examples which give the extent of an applicant's relation to the engineering work. It is not sufficient to say that he was in charge of the design of a new air conditioning unit. His board must know such things as the manufacturer's name, capacity range in tons of refrigeration, type of compressor and horsepower, and refrigerant used. If possible, he should show what new features were added and in what way or ways this unit held advantage over other makes. He must also indicate the length of time spent on this work assignment.

He must distinguish between professional and subprofessional experience. The design or supervision of construction of machines and machinery, power-plant equiment and tools are considered professional.

The operation of machinery, foundry and machine shops may be considered subprofessional for the purposes intended. In this category are also included drafting, detailing, shop drawings, tracing, layout work, routine computing under competent direction, routine testing under competent direction, inspection of materials, maintenance and repairs, and welding.

In other words, where the record shows a legal minimum number of years of creative engineering work requiring the application of the engineering sciences to the investigation, planning, design and construction of engineering works it is considered qualifying experience. **Creative engineering experience is not merely the layout of the details of design, nor merely the performance of engineering calculations, writing of specifications or making tests. It is a combination of these things, plus the exercise of sound judgment, the evaluation of economic and social factors in arriving at decisions, and the rendering of these decisions to his client or employer . . . this all constitutes qualifying experience that should be part of the record.**

Showing Job Progress: The application must show progression to more important work on the



Progress of engineering registration. Number of registered professional engineers has more than doubled in the past ten years. Nearly ten times as many engineers are now registered as in 1930. (Courtesy, National Council of State Boards of Engineering Examiners)

job. It must prove more than the routine observation and recording of technical data and more than systematized and unvarying operations. The applicant must show more than a passing interest in his work and must have progressed professionally. Experience must be diverse, for the boards do not license the specialist; they license the engineer.

Knowledge of the basic fundamentals of science and mathematics alone does not satisfy the requirements. Evidence of the ability to use these fundamentals in the design of engineering works is adjudged "acceptable" experience. **Design in its broadest sense—not solely confined to making drawings—is the intent.**

Experience Credit: Most boards allow credit, subject to certain restrictions, for the engineering experience of the applicant. They do not allow experience credit for (1) teaching of nonengineering subjects in an engineering college or elsewhere; (2) work projects performed before an applicant would normally complete high school; (3) assignments in branches of the armed services which do not involve engineering; (4) the work periods of a co-operative college course; (5) vacation periods between the terms of a college course; (6) sales work which does not involve the use of engineering knowledge; (7) employment of a nonengineering nature even though it be in connection with engineering works; (8) the duties of a contractor, superintendent or foreman on construction or factory work unless such work involves engineering practices; (9) correspondence-school courses in engineering.

When the duties of an applicant involve performance in both engineering and nonengineering assignments, it is general practice to grant partial experience credit to the extent warranted by the actual situation. In certifying his experience record, the applicant should carefully designate the actual engineering duties performed by description and extent of time involved, particularly in employment which may not be entirely of an engineering nature.

Experience may be acquired in the applicant's home state or elsewhere. Engineering experience acquired prior to graduation from college may be accepted if it does not fall within one of the defective classifications previously listed. A year of graduate study in engineering which has led to a master's degree may be accepted as one of the four years of acceptable experience.

The Professional Engineer's License

In most states the boards license the engineer and not the specialist. Registration certificates in these states do not list the branch of engineering, although the branch is listed in the roster or noted on the application. Some fifteen states show the man's branch on the certificate.

All written examinations include a professional group of tests covering certain branches of engineering: Mechanical, Chemical, Civil, Electrical, Heating & Ventilating, Aeronautical, Agricultural, Ceramic, Industrial, Mining & Metallurgical, Public Health, Radio, Safety, Structural, Highway, Railway, Sanitary, Machine & Tool Design. The order shown in no way reflects the degree of importance.

New York State and Ohio test for certain branches, but the certificate licenses the Professional Engineer. California, Michigan and Oregon—among others—both test and license in the branches.

The National Council of State Boards of Engineering Examiners (NCSBEE) seeks the "oneness" of the engineering profession. Through registration laws, engineers have recorded the principle that engineering is one profession, although specialties may be many. Law and medicine have as many specialties as engineering, but lawyers and doctors would never consent to the legal subdivision of their professions.

Whether a man writes E.E., M.E., Chem.E. or C.E. after his name, he has fundamentally the same common basic educational training, the same governing professional qualifications, the same method of analytical approach to technical problems, the same ideals of professional practice, and the same interest in the profession's standing and reputation.

Scrapless Laminations

REDESIGN of General Electric Co.'s fluorescent lamp ballast laminations resulted in a complete elimination of scrap. Size, weight and cost of the ballast assembly were also reduced.

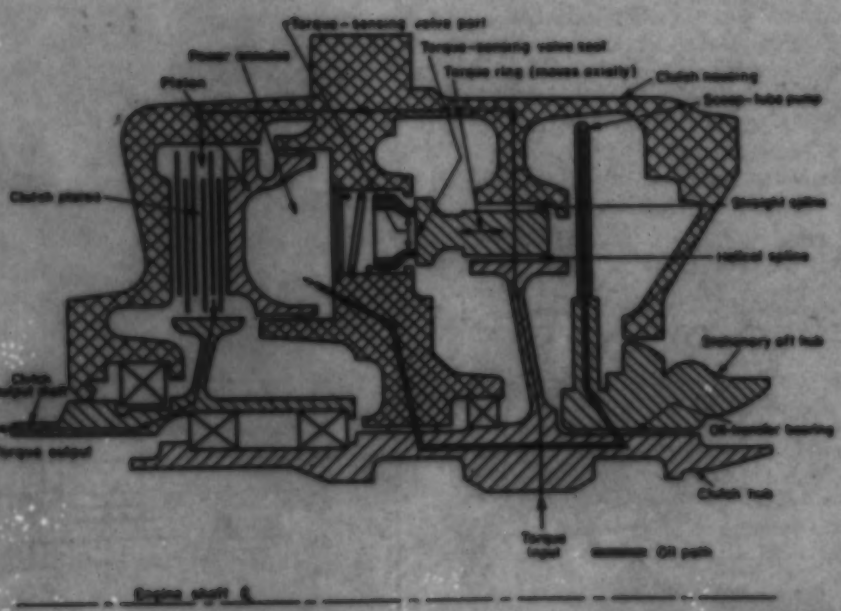
Stampings for the core side laminations were formerly made in an E shape, *Fig.* 1, left. Present design, *Fig.* 1, right, enables the side configurations to be backed up for continuous scrapless stamping. Cross-section dimensions of the assembly are reduced by about 28 per cent with a weight saving of 30 per cent. Shipping cost reduction is an added indirect saving.

Fig. 1—Old style ballast lamination, left, was stamped in an E shape. New style, right, eliminates scrap

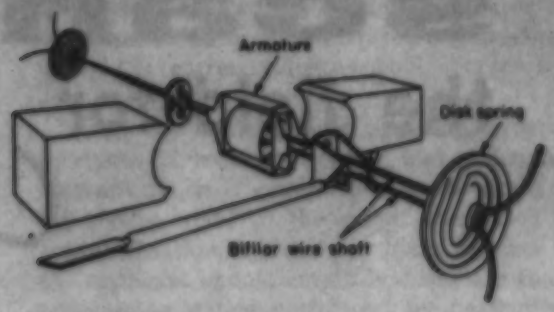
scanning the field for Ideas

AUTOMATIC TORQUE CONTROL is provided in a lightweight, high-horsepower transmission design based on clever mechanical control of hydraulic fluid forces. Developed by W. N. Stone and N. R. Richmond of the Kaman Aircraft Corp. for application on helicopter rotor-drive systems, the multiple-disk clutch employs kinetic energy of high-velocity oil to create clutch-plate engagement pressure.

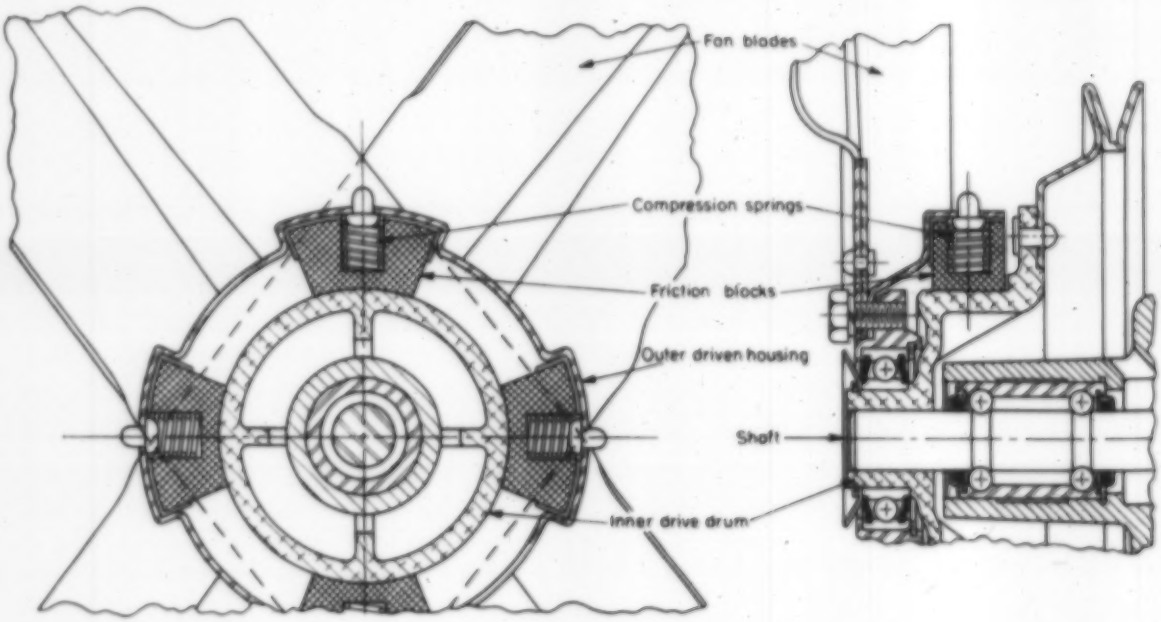
To engage the multiple wet disks, it is only necessary to apply rotating driving power to the clutch hub. This action immediately imparts a slight rotational displacement between clutch hub and clutch housing, causing the torque ring to move left by virtue of a *helical spline* located between clutch hub and torque ring; a straight spline is placed between torque ring and clutch housing. Axial direction of torque-ring traversal is determined by the sense of torque through the clutch. Movement of the torque ring far enough left presses an integral Teflon valve seat tightly against the torque-sensing valve port permitting a build up of hydraulic pressure in the power annulus. By means of a stationary scoop-tube, pressure energy is derived from the kinetic energy of high-velocity oil rotating in outer part of clutch housing. Under load, oil pressure to the piston increases as speed rises, reaching a maximum value at full speed. However, in the event of input power reduction or failure, torque imparted by the rotor to the clutch housing immediately exceeds that delivered to the clutch hub. This reversal of torque sense forces the helical spline to move the torque ring right which releases oil pressure accumulated in the power annulus. This action immediately disengages the clutch plates and permits full overrunning of clutch output-shaft load.



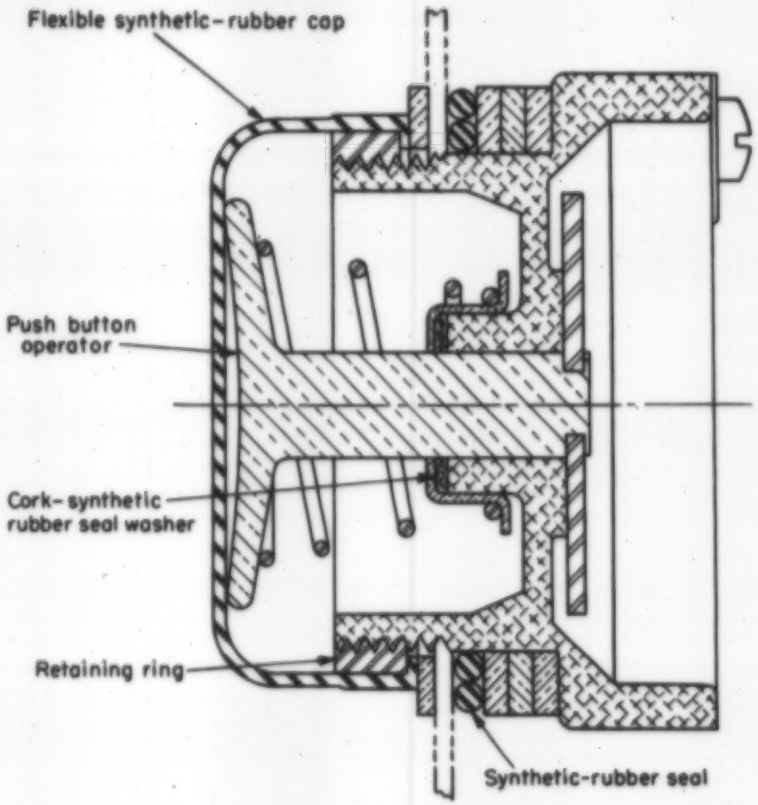
BIFILAR WIRE SHAFTS eliminate conventional pivot-and-jewel construction and provide a rugged support mounting for precision rotating instrument assemblies. In the Simpson-Greibach suspension type meter movement, the rotating armature is held in place by two fine wires which are kept under precise tension by means of disk springs mounted in the adjustable ends of the movement cartridge. High reliability under adverse conditions is provided by the suspension principle which, in actual precision instrument applications, has been successfully shock tested to 500 g's without appreciable loss in accuracy.



AUTOMATIC SPEED CONTROL to prevent excessive power transmission in rotating shaft connections is provided by a centrifugal slip clutch developed by Lipe-Rollway Corp. Designed primarily for automotive applications, the clutch provides full engagement under normal load and speed conditions but will begin to slip automatically at a predetermined maximum speed. Clutching action is produced by a three-element construction, consisting of an inner drive drum connected directly to the power source, an outer driven housing, and a frictional control unit located between the drum and housing. This frictional control unit consists of a series of friction blocks held in place by compression springs mounted to the housing. When operating at low speeds, friction between the drum and blocks prevents slippage, and the three coupling elements rotate as a unit. When the drum exceeds a predetermined speed, centrifugal force thrusts the blocks outward against the springs, reducing the pressure between blocks and drum, and slippage begins.



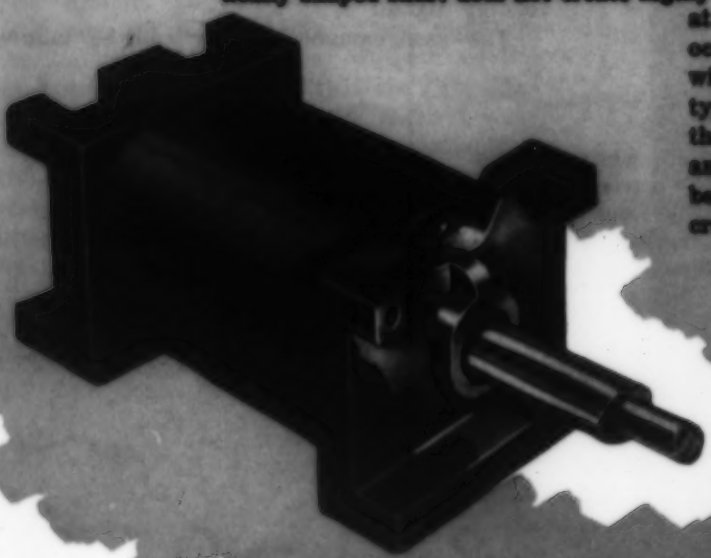
IDEAS

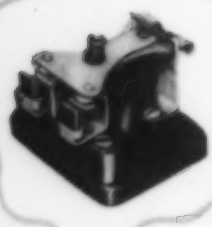


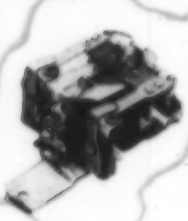
OILTIGHT SEALING of electric-control pushbutton operators is provided by flexible synthetic-rubber caps. Made of Hycar and designed by General Electric, the colored molded covers prevent dust, dirt, ice, oil, grease, etc., from getting on the pushbutton - operator shaft. Actually the sealing technique supplements the regular oiltight switch seal around the pushbutton shaft.

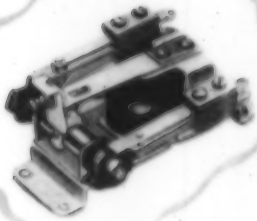
The caps are fitted over threaded retaining rings to permit tight, secure sealing and to allow easy application and removal.

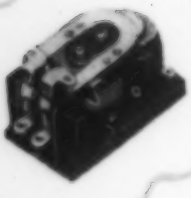
ELLIPTICAL PISTON ROD offers a unique means of preventing rotation of sliding shafts. Used in push type clamping cylinders manufactured by Alkon Products Corp., the design eliminates the need for external guide bars or ways. Also, under torque, the elliptically shaped shaft does not create highly concentrated lines of stress at any point such as would occur at the corners of shafts with square, rectangular, etc., types of cross-sections. Thus, the design shape prevents any gouging away at softer bearing material which would create a sloppy fit.



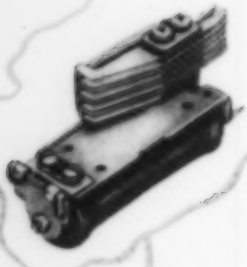






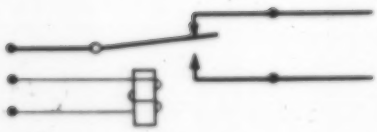


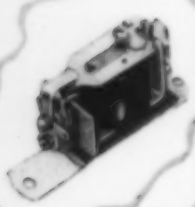
Factors to consider in specifying RELAYS



By James F. Rinke

Director of Engineering
Potter & Brumfield Mfg. Co. Inc.
Subsidiary of
American Machine & Foundry Co.
Princeton, Ind.

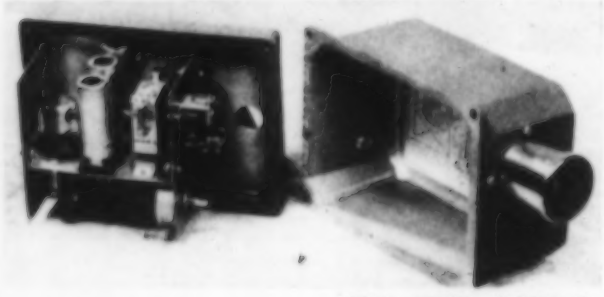




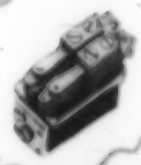
AUTOMATIC and semiautomatic switching of electric and electronic circuits is fast becoming a design must in most machines and equipment used in domestic, industrial, commercial and military fields. Many of the circuit functions in such equipment are controlled and performed by amplifying, regulating and on-off devices which have no moving parts, such as electronic vacuum tubes, transistors, thyratrons, magnetic amplifiers and the like. However, the ultimate control function associated with these circuit elements is often accomplished by means of electro-magnetic relays. These units can control a multiplicity of circuits simultaneously and in various combinations from a relatively low-energy signal.

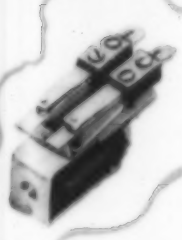
The electromagnetic relay can be tailored to

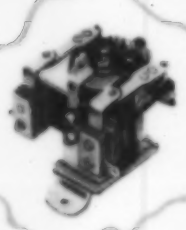
Photoelectric control unit which actuates automatic counters. Two relays are used in each control unit — one for tube warm-up and tube failure protection, and the other for photoelectric control

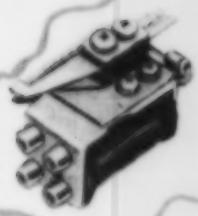


Photo, courtesy Autotron Co.

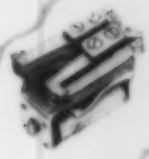








- **Number of circuits**
- **Circuit characteristics**
- **Type of switching**
- **Actuation power**
- **Operating speed**
- **Duty cycle**
- **Life expectancy**
- **Environmental conditions**
- **Physical requirements**
- **Cost**

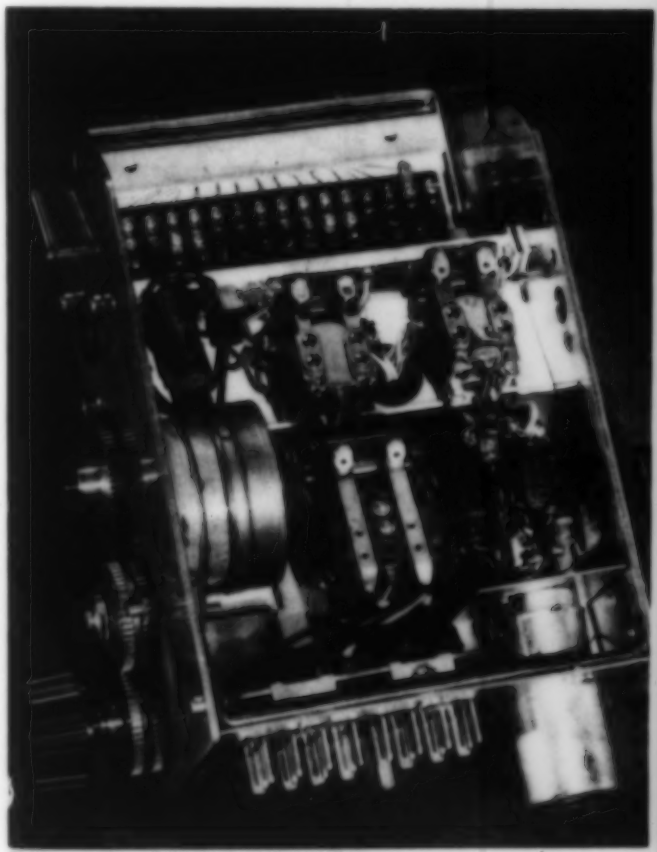


provide high-conductance switching of almost any conceivable combination of currents and voltages and can be operated by power from a wide variety of sources. However, in order to apply such a component properly and most successfully, its performance capabilities as well as its limitations should be thoroughly understood.

Most of the important design factors to consider in selecting and applying relays are listed in *Table* 1. A careful and realistic evaluation and balancing of each of these points will often result in the most satisfactory relay from the standpoint of both performance and cost.

The design factors in *Table* 1 are divided into four major categories: (1) contact system, (2) actuator system, (3) environmental conditions, and (4) physical requirements. These might be said to be listed in the order of their relative importance since it is obvious that the first function of any relay is to switch the required number of contacts. The ability of these contacts to handle the electrical loads involved throughout a certain minimum expected number of operations is dependent upon relay design which is completely dependent upon relay specifications.

The relay actuator or coil system is next in importance, because this element provides the mechanical energy to operate the contact system.



Photo, courtesy Industrial Analyser Corp.

Automatic recorder unit with relays to control impulses which actuate the recorder mechanism

Environmental conditions under which a relay is required to operate will have an important effect upon its performance, too, and must be taken into account. In military applications, especially, this design aspect may assume major importance, but it must always remain secondary to the actual switching function and the means by which this function is activated.

The last of these four categories, physical requirements, may be considered of less importance than the other three, since it will often involve merely a preference in the matter of size, shape and mounting arrangement. Except in critical applications, these factors can usually be modified in favor of the electrical and environmental aspects. Also included in the section physical requirements is discussion of types of termination, enclosures, markings and finishes.

Contact System

Obviously, the basic function of any relay is to switch one or more electric circuits. This switching action, which of course takes place at the contacts, is electromagnetically controlled by the relay coil or actuator system. A thorough evaluation must be made of the characteristics of electric energy in *each* circuit being switched. This is likewise true of the power available to actuate the relay. Each of these circuits influences such factors as relay performance, reliability, size, shape and cost. First, factors affecting the contact system will be discussed.

Contact Arrangement: The first factors to consider in the contact system are contact arrangement, number of different switching circuits and the type of switching to be performed in each circuit. There are many possible combinations that can be provided, and usually several of these can be furnished on the same relay. Symbols for the most commonly used contact arrangements are shown in *Fig.* 1. Caution should be exercised in the specification of more contacts than are actually needed. Often there is a tendency to specify a form C (single-pole, double-throw switching arrangement), when actually the switching function requires only a form A or form B contact. Apparently, this reasoning is based on the following assumptions: (1) the extra contact takes up little extra space (2) it probably adds only slightly to the cost and (3) it might be useful to have such a slightly more complex relay for possible use in some other unforeseen circuit application. Admittedly these assumptions are somewhat valid and may be justified in some cases, but extra contacts always have a detrimental effect on the amount of power available to operate essential contacts besides increasing the time and difficulty of adjusting the relay. Thus, such unnecessary complexity may add considerably to relay cost.

Contact Electrical Loads: The next factor of

Table 1—Check List of Relay Specification Factors

Contact System

1. Contact Arrangement Factors
   - a. Number of contacts
   - b. Type of switching on each contact
     Normally open, normally closed, single-pole single-throw, single-pole double-throw, make-before-break, break-make-before-make, make-after-make, double-make, double-break, etc.
2. Load Characteristics on Each Contact
   - a. Open-circuit voltage
   - b. Type of current
     Battery, dc line, rectified ac, ac—frequency and waveform, etc.
   - c. Amount of current
     Maximum surge, normal or steady-state, etc.
   - d. Type of load
     Resistive, inductive, capacitive, motor, lamp, etc.
   - e. Amount of load impedance
3. Duty Cycle
4. Life Requirement
5. Circuitry

Actuator System

6. Characteristics of Coil Energy
   - a. Type of power source
     Battery—dry or storage, dc line, ac line, electron-tube plate circuit, rectified ac, etc.
   - b. Frequency
   - c. Waveform
   - d. Amount of voltage or current available
     Nominal, minimum, maximum, maximum residual
   - e. Required operating voltage or current
     Pull-in, drop-out, differential, tolerance
7. Coil Resistance
8. Other Components in Coil Circuit
9. Duty Cycle
10. Operating Speed on Pull-in and Drop-out
    - a. Normal
    - b. Fast
    - c. Time delay

Environmental Conditions

11. Standard Industrial Specifications
    - a. Military
    - b. Underwriters' Laboratories
12. Ambient Operating Temperature
    - a. Normal
    - b. Minimum
    - c. Maximum
13. Atmospheric Conditions
    - a. Moisture
    - b. Dust and dirt
    - c. High humidity
    - d. Corrosive or explosive atmospheres
    - e. Altitude
14. Shock, Vibration and Acceleration Data

Physical Requirements

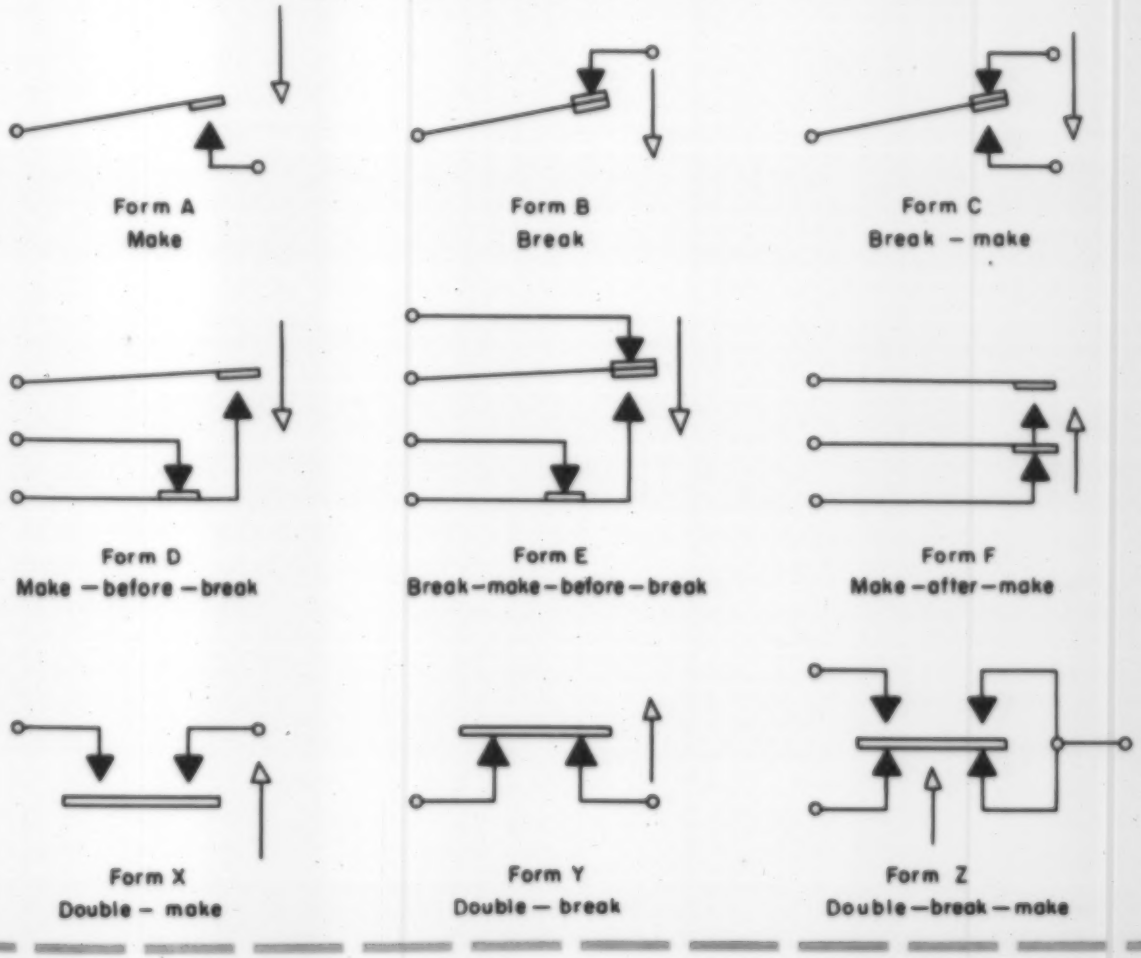
15. Space Requirements
    - a. Size and shape
16. Mounting Method
    - a. Threaded studs or holes
    - b. Brackets
    - c. Plug-in bases
    - d. Connectors
17. Electrical Connection Method
    - a. Screws or threaded studs
    - b. Solder terminals
    - c. Plugs or AN connectors
    - d. Quick-disconnect tabs
18. Protective Enclosures
    - a. Plastic or metal
      Dust type, hermetically sealed, etc.
19. Finishes
20. Markings

major importance concerns the characteristics of electrical loads the individual sets of contacts will be expected to handle. Whenever possible, a circuit diagram of the application requiring a relay or relays should be supplied with specifications of voltage, current, etc., marked on each circuit. Here, many variations are possible and it is important to give *actual* load conditions on each relay-switched circuit in the machine. This point cannot be stressed too strongly, since it is conventional relay design practice to incorporate a safety factor that is adequate and consistent with the expected application requirements. If this procedure is not followed, the load-carrying capabilities of the relay may be all out of proportion to the actual needs. Specifications showing contact current loads which greatly exceed actual load values will result in the selection of a larger, more powerful and more expensive relay without necessarily obtaining a more reliable relay. Thus, contact loads should be given exactly as calculated or measured such as 1.37 amperes or 0.025-ampere instead of "round" or estimated figures.

Of course, the value of open-circuit voltage should be specified including whether this voltage is ac or dc. Additionally, if the contacts are handling alternating current, the frequency should be specified.

Great importance must also be attached to the *type* of load being handled by the contacts. If the load is merely resistive with no inductive or capacitive reactance, then this fact should be clearly stated in specifications. On the other hand, it is even more important to indicate any variations from a purely resistive load. If the load is inductive, then an effort should be made to determine the power factor or the amount of inductive reactance. In lieu of this information, a description of the *kind* of device which represents the load such as a solenoid, filament lamp, contactor, etc., can be quite useful. For example, when relays are designed for tungsten filament lamp loads, consideration is given to the fact that the ratio of hot to cold filament resistance is almost 10 to 1. This means that the contacts used to close the circuit to a lamp with a cold filament are required to handle an initial current of practically 10 times the steady-state current value existing after the filament comes up to temperature. Thus, a 2-ampere contact, which might appear to be adequate to operate a 200-watt lamp on

Fig. 1— Electrical symbols for nine commonly used contact forms



a 115-volt ac source, is completely inadequate since the initial surge current would be in the order of 20 amperes. Such high surge currents may cause sticking or welding of the contacts unless proper contact materials are used.

If the load is a motor, complete information should be given on size and horsepower rating along with the starting surge current if this information can be obtained.

Duty Cycle: Another factor related to contact performance is duty cycle. Specifications of this factor should include the actual duration of time contacts are expected to be closed and open. The factor of frequency of operation should be included with this information since it will have a large effect on the relative life of contacts. Some contact systems fail after relatively few operations when operated at a high frequency under certain load conditions, whereas the same loads could be easily handled by the same contacts for a large number of operations when switched at a slower rate. Speed of operation is closely related to the heat developed at the contacts, and this must be taken into account in the relay design.

Life: Care should be exercised in estimating the minimum acceptable number of trouble-free operations as a projected life requirement. Unrealistic specifications of life may result in an unnecessarily expensive relay or one which is next to impossible to manufacture. For example, a relay which operates only twice per day, such as in a street-lighting application, will need to operate only 730 times during a year. A projected 10-year life requirement would indicate the need for a relay to operate reliably slightly over 7300 times. Obviously, a specification of 100,000 or even 50,000 operations would be out of line for this application. Of course in many applications, thousands or even millions of operations are required. A realistic appraisal of life will permit the design of a relay that embodies the most suitable contact elements to fit the application.

Other Design Factors: Selection of contact material as well as contact size, operating pressures and gaps depends entirely on application requirements. Selection of these in all cases must be left to the relay manufacturer, provided all of the load information is available.

Actuator System

The second major specification consideration concerns the actuator or coil system of a relay. As with the contact system, the actuator system has quite an influence on relay design. The effects of the type of power supply plus other circuit components which may be connected in the relay coil circuit must not be overlooked. Here again it is essential to include in relay specifications a detailed circuit diagram of the particular part of the equipment circuit in which the relay is to be operated.

Coil Power Source: A careful evaluation must be made of the type of power source available and the amount of energy that can be furnished to operate the relay. Relay coils are commonly operated directly from an ac or dc power line or they may be operated from a storage battery or dry battery. In many applications, relays are used in plate circuits of vacuum tubes in which they are generally provided with relatively high-resistance coils and operated on comparatively small amounts of current. Complete specifications of the mode of operation are essential since provision must be made for the maximum range of current or voltage fluctuations in designing the relay coil system.

AC or DC Line: Relays, which are operated directly from an ac or dc power line, or from a transformer whose primary is connected to an ac line, must operate properly at the absolute minimum line voltage to be encountered and will also be expected to operate continuously without overheating at the maximum line voltage. For the standard 115-volt ac power line, minimum voltage is usually considered to be 90 volts and the maximum 130 volts. This means relays designed for such service are required to pull-in at some point below 90 volts and to be absolutely stable at this voltage; they also must operate at a safe temperature with 130 volts continuously applied to the coil.

Battery Power: Maximum and minimum voltages must be given for battery-operated systems, too, although with somewhat different percentage values. A storage battery, for example, is considered to be at its minimum operating level when the voltage drops 25 per cent below nominal voltage or voltage may rise as much as 25 per cent above nominal under heavy charging conditions. Thus, a relay designed for a 24-volt (nominal) storage battery must be able to pull-in at some value safely below 18 volts and be completely stable at this voltage. Likewise, this same relay must also be capable of operating continuously at 30 volts without overheating.

Plate-Circuit Power: Relays operated by the power available in plate circuits of vacuum tubes are subject to a wide range of operating conditions which depend upon the type of tube used and actual currents present in the plate-circuit system. In such cases, a determination should be made of the minimum amount of current present in the circuit under the most adverse combination of conditions. A current no lower than this actual value should be specified to operate the relay. As in the contact circuits an additional safety factor should not be assumed. Specifying a relay actuat-

ing system with unnecessary sensitivity leads to additional difficulties in relay manufacture and adjustment. This can only result in a more costly component.

In any case, specification values of current or voltage at which the relay is required to pull-in or drop-out must include a tolerance of some kind. For example, suppose a relay actuator-system specification only includes information that a relay must pull-in at 5 volts and drop-out at 2 volts. Now in this case it is very likely that the application requires a relay that will be fully operated at 5 volts or at some voltage below this value, and will also drop-out at some voltage above 2 volts. However, without tolerance data this assumption cannot be safely made. Actually, the specification of a drop-out point on a relay should be omitted entirely unless this point is really critical in the application. In most applications, it is usually sufficient to specify the minimum operating current or voltage so that the pull-in point can be established at this value or slightly below it. The matter of drop-out point can be left up to the relay manufacturer as long as drop-out occurs safely above complete cut-off of current or voltage. In certain applications, especially those involving plate-circuit operation, a certain amount of residual current is present and here it is necessary to establish a drop-out value of current which will be safely above the maximum residual level.

The relationship between the pull-in point and the drop-out point with respect to operating currents or voltages is known as the *differential*, and this should always be made as large as the performance requirements of the application will permit in order to produce the most reliable relay at minimum cost. Of course, requirements of certain types of circuitry necessitate the specification of extremely close differentials. If these are realistically expressed, special consideration can be given to this particular point in the design of the relay. However, it should be borne in mind that relays requiring a close differential are always more difficult to adjust and hence are more expensive.

Rectified AC: Another factor to consider is the possibility of obtaining a more efficient relay by specifying a coil system designed for dc and connecting it to a small rectifier for operation from an ac source. While many fine ac relays are available, these relays are far less efficient, for comparable size, than a dc relay in converting electrical energy in the coil to mechanical energy to operate the contact system. This factor often creates a serious problem, especially when attempting to provide miniature relays for operation directly from an ac source. In such cases, incorporation of a separate rectifier in the relay operation circuit is advised to permit the use of a dc relay instead. When such relays are to be provided with an enclosure of some sort, it is entirely practicable for the relay manufacturer to mount such a rectifier inside the enclosure, *Fig.* 2. While this type of construction will usually result in a slightly higher cost for the component, an increase in operating efficiency will result. Also, a more reliable relay can be provided which will have an operating life several times that of a comparable straight ac relay.

Many unique variations in performance can be provided by proper coil design in connection with variations in the magnetic circuit which will enable relays to operate from full-wave or half-wave rectified ac sources or from unusual wave forms such as may occur in the plate circuit of a thyratron tube. Detailed information should be supplied which completely defines the wave shape

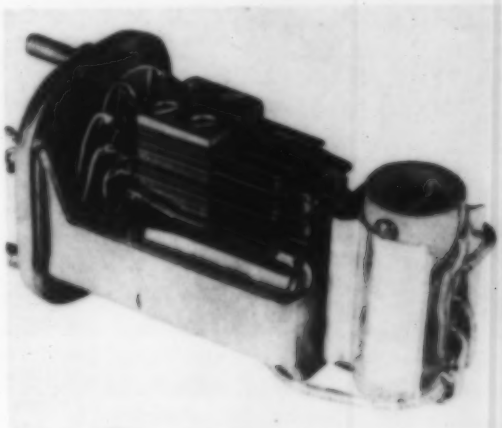


Fig. 2—Dc relay with self-contained rectifier for ac operation. Threaded studs are for mounting

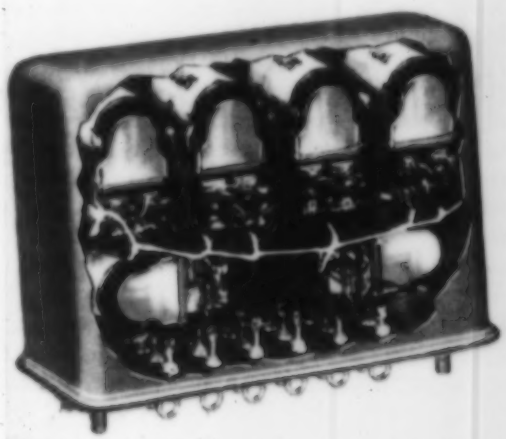


Fig. 3—Six relays built in a single protective enclosure, hermetically sealed. Unit is stud mounted

Fig. 4 — Hermetically-sealed plug-in relay, miniature type. Plug-in base fits standard miniature tube socket

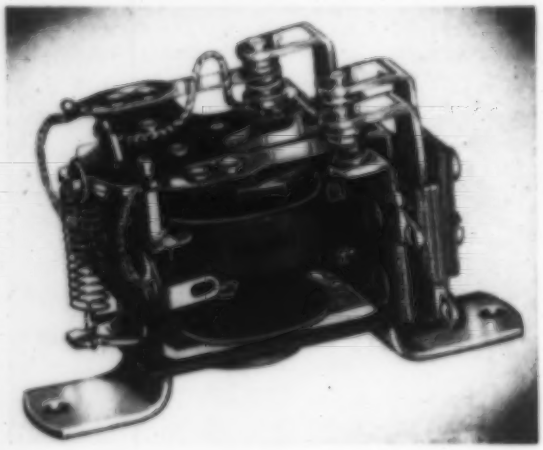


Fig. 5—Open relay with mounting bracket extensions

present in the coil system of the relay.

Coil Resistance: Specifications of coil resistance and any associated tolerances should be given in such a manner as to provide maximum leeway in coil design. Each particular type of relay in any manufacturer's line is provided with a certain definite amount of winding space, and the most efficient relay operation is provided when this space is completely filled. Selecting one specific value of coil resistance may result in the winding space being only partially filled with a particular wire size, whereas the next larger diameter wire could not be used because it would overfill the space. When changing from one wire diameter to another, assuming a full winding in each case, a factor of 0.65 may be applied as a rough way of estimating change in resistance. This means that if the resistance of the full coil wound with a certain size wire has been established then the same coil wound with the next larger diameter wire would have approximately 65 per cent of the resistance of the first coil.

Some difficulty may be encountered with coil specifications when relays have been obtained from one supplier and a similar type of relay is desired from another supplier as an alternate source. It often occurs that the winding space provided by the new supplier, even on a similar type of relay, may be sufficiently different that a full coil on his relay would not provide the same coil resistance as that of the first supplier.

It should be apparent that coil-resistance specifications should be stated in very broad terms, such as merely indicating the maximum amount of coil operating current to be permitted at a certain voltage or the maximum energy in watts which can be tolerated in a given application. Specification tolerances must be considered and should be kept as broad as possible for most economical relay design. A tolerance of ± 10 per cent is commonly applied to manufacturing specifications for relay coil resistance. Closer tolerances can be held, if required, but they may add considerably to cost. In all cases, of course, in specifying a coil resistance even with a ± 10 per cent tolerance, assumed ambient temperature must be indicated since resistance of copper wire changes rather radically with temperature. When an ambient temperature specification is not given, it is understood throughout the industry to be at a standard temperature of 25 C.

Details of coil construction should be left entirely to the relay supplier since he is always in the best position to determine the type of winding and insulation required to meet the various conditions under which the relay will operate.

Duty Cycle: It is quite essential that information be supplied concerning the duty cycle on which the coil system is to be operated. A relay, for example, which is to be continuously energized over a long period of time will require a coil incorporating structural features that will enable it to have maximum life under these conditions, while one which is operated intermittently with only very short periods of energization may be able to use a less expensive construction. The actual times involved in the "off" and "on" periods as well as frequency of operation permit the most efficient relay design for a particular application.

Operating Speed: Another relay performance characteristic which is rather closely associated with the actuator system is the operating speed on both pull-in and drop-out. In some applications this factor may become highly important. Most small relays will completely transfer their contacts within 25 milliseconds or less after energization of the coil while the drop-out speed after de-energization is usually somewhat faster. However, it is entirely possible in many relay designs to provide much faster operating speeds if such is required by the application. Considerable discretion should be used when calling for high-speed relay operation since adjustment variations required to meet these conditions do not tend to improve reliability of the contact system and usually increase cost of the component.

It is sometimes desirable to incorporate a certain amount of operational delay, so that the contact system will be operated only after a certain minimum length of time has elapsed after energization or de-energization of the relay coil. Within very definite limitations for each particular relay type, a certain amount of delay can usually be introduced by incorporating a heavy short-circuited winding surrounding the same core on which the coil is wound. This winding resists build-up or decay of the coil magnetic flux for a short period of time. This design feature can only be applied to dc relays, and the amount of time delay available on either pull-in or drop-out is generally limited to 100 milliseconds or less, depending upon the particular type of relay structure under consideration. Other methods of providing longer periods of time delay which make use of additional circuit components are well known throughout the industry and will not be discussed here since they do not affect the relay coil design.

Environmental Conditions

An important factor in any relay specification is the environmental conditions under which it is to be required to operate. Environmental conditions may have an important bearing upon relay performance and must be taken into account in design. If military specifications are involved in an application, not only the necessary information concerning the particular specification numbers should be given but also specific data on variations included in these specifications. For example, it is not sufficient merely to indicate that a relay must meet MIL-R-5757B or MIL-R-6106A, because there are several temperature ranges and different degrees of shock and vibration tests outlined in these specifications. Those conditions which most nearly meet the requirements of the application should be selected.

In addition to the restrictions imposed by military specifications or requirements of Underwriters' Laboratories as they may be applied, it is always advisable to spell out, in as much detail as possible, the complete range of environmental conditions which the relay may be expected to encounter in actual service.

Temperature: An environmental specification which is frequently overlooked is the matter of ambient operating temperature. Maximum and minimum temperature values at which a relay will be required to operate are essential, since it is always necessary to compensate for the coil-resistance change between these temperature extremes when setting up adjustment specifications for pull-in and drop-out. For example, one of the military specifications requires that a relay be capable of operating at a maximum ambient temperature of 85 C. If a 24-volt dc relay is being considered for such an application, it is necessary for this relay to pull-in at 18 volts or less at the *maximum* ambient temperature. It would not be sufficient to specify the minimum operating voltage at room temperature (20 C) in this application because the value of coil resistance would increase approximately 16 per cent from room temperature up to 85 C. This resistance increase would reduce the amount of current in the actuator coil so much that at the 18-volt level the relay would not operate. Actually, this relay would have to be designed to pull-in at approximately 15 volts at room temperature in order to make sure it would operate at 18 volts at 85 C. This example shows why it is necessary to set up the specifications which will guarantee a proper current level in the coil at the *highest* operating temperature.

In establishing a minimum drop-out voltage it must also be kept in mind that resistance of the relay winding is reduced considerably at low temperatures. If the relay, discussed in the previous example, is required to drop-out at 5 volts or more at a temperature of −65 C, the drop-out point at room temperature may be as high as 10 or 11 volts. Since the pull-in point on this relay would be 15 volts at room temperature, the requirement for a close-differential relay is rapidly approached. This illustrates why pull-in and drop-out points should be kept as far apart as possible when specifications are being prepared.

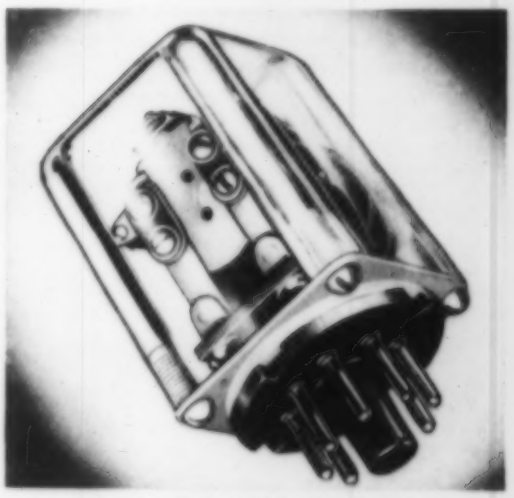


Fig. 6—Relay with standard octal plug. Transparent-plastic dust cover permits inspection of working parts at any time

Atmospheric Conditions: The probable presence of moisture or high humidity as well as corrosive or explosive atmospheres and unusually dusty or dirty conditions should be evaluated and included in relay specifications. These factors will affect the type of protection provided for the coil as well as the type of plating or other finish which may be required on the metal parts of the relay. Under extremely deleterious conditions it may be necessary to provide protective enclosures such as the hermetically sealed units shown in *Figs.* 3 and 4.

Shock and Vibration: In most military applications the effects of shock and vibration as well as linear acceleration have to be considered but frequently these factors are overlooked in civilian applications. The need for these specifications is apparent. It is entirely possible to make certain types of relays that will resist the effects of vibration at a level of 20 g's up to 2000 cps. However, specifications should give only the worst shock or vibration conditions which will actually be encountered during the life of the equipment. Padding vibration and shock data will not only automatically increase cost, but also it may set up completely impossible design conditions.

Physical Requirements

The matter of physical requirements includes such details as space available in which to locate the relay and the actual size and shape of the relay desired, as well as the type of mounting and termination. Also, enclosures, markings and finishes are pertinent.

Size and Shape: Generally, the type of equipment will dictate the basic physical aspects of the relay. If space becomes critical, all possibilities of position, location and redesign should be explored. Then in detailing relay specifications maximum limitations should be given on the three dimensions determining the size of the relay since this factor may seriously limit performance capabilities. Manufacturer's catalog data on a particular type of relay selected will determine roughly the basic dimensions as well as mounting and termination. However, it is usually best to wait until agreement has been made upon the *type* of relay required for a given application based upon performance considerations before making a final determination of the space to be allotted.

Mounting Methods: Factors which determine the method of mounting a relay will again depend largely upon the general structure of the equipment and whether the relay is to be furnished without an enclosure or in a dust cover or hermetically sealed container. Most open relays are normally provided with bracket extensions having clearance holes for standard machine screws, *Fig.* 5, to permit mounting to a chassis or panel surface. Variations of this type of mounting are entirely feasible for both open type and enclosed relays such as the use of projecting threaded

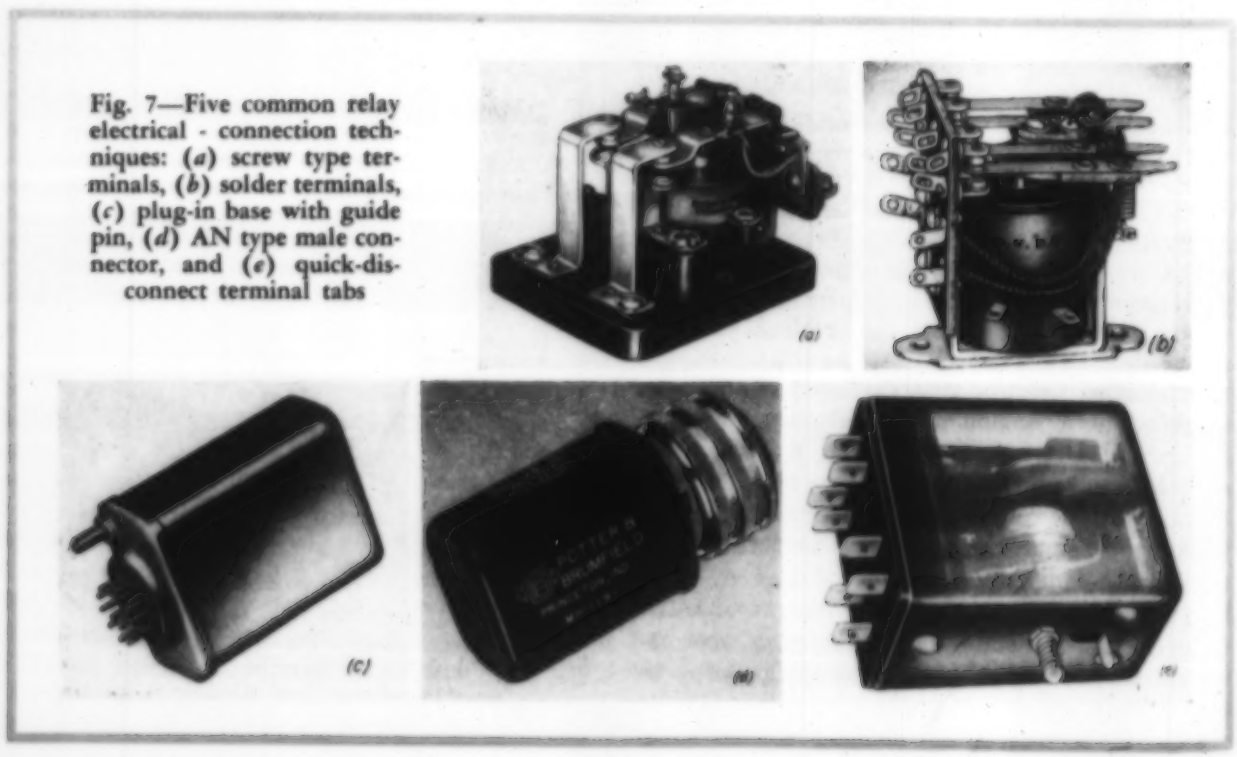


Fig. 7—Five common relay electrical - connection techniques: (*a*) screw type terminals, (*b*) solder terminals, (*c*) plug-in base with guide pin, (*d*) AN type male connector, and (*e*) quick-disconnect terminal tabs

studs, *Figs.* 2 and 3, or internally threaded tapped holes for mounting from the opposite side of a panel or chassis. Relays furnished in an enclosure of some kind are frequently mounted by means of a standard size plugs, *Figs.* 4 and 6, which also serve to make electrical connections when used with mating sockets. This method is sometimes also used on relays without an enclosure but the practice is not common and is not generally recommended.

Terminals: In considering the type of terminals to which electrical connections are to be made, those most commonly available are the screw or stud types, solder terminals, plugs or AN connectors and the quick-disconnect types.

The use of screw type terminals, *Fig. 7a,* is generally limited to the larger types of open relays and is usually recommended for heavy-duty appliance or control use. Certain types of relays in the various manufacturers lines are normally provided with screw-type terminals, and it would be difficult to alter this arrangement on these particular relay types.

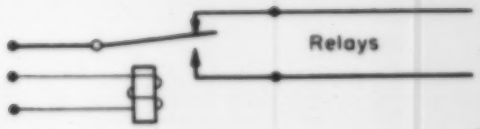
The smaller types of relays on the other hand are normally furnished with flat-metal solder terminals, *Fig. 7b.* Also, it is common to use wire type solder terminals, such as shown in *Fig.* 3.

Since relays are generally recognized as ultimately fallible devices in the manner of electronic vacuum tubes, the use of plugs, AN connectors and quick-disconnect terminals is rapidly coming into general usage. This is especially true where rapid replacement may be of considerable importance in restoring equipment to use after a relay failure. A large percentage of military equipment is presently being designed to use either plug-in type relays (*Figs.* 4, 6 and 7*c*) which either fit into standard radio-tube sockets or make use of the AN series connectors (*Fig. 7d*). These methods of connecting and mounting relays are completely positive even under relatively severe external mechanical stresses, when used with a properly designed clamp or other device to hold the unit in the socket.

The quick-disconnect type of relay, *Fig. 7e,* is finding wide application in household appliance and automotive applications.

Another method of mounting and termination that should not be overlooked in the modern trend toward miniaturization is the use of special terminal tabs as shown in *Fig.* 8. These tabs are designed for mounting on printed-circuit plates which are commonly connected by the dip-soldering technique. Many types of relays normally furnished with other types of terminals may be adapted to this terminal-tab design without radical changes in the relay itself.

Protective Enclosures: There are many varied types of protective enclosures available from most relay manufacturers. These include simple clear-plastic dust covers (*Fig.* 6) or metal enclosures (*Fig.* 9) which may be mounted separately. The

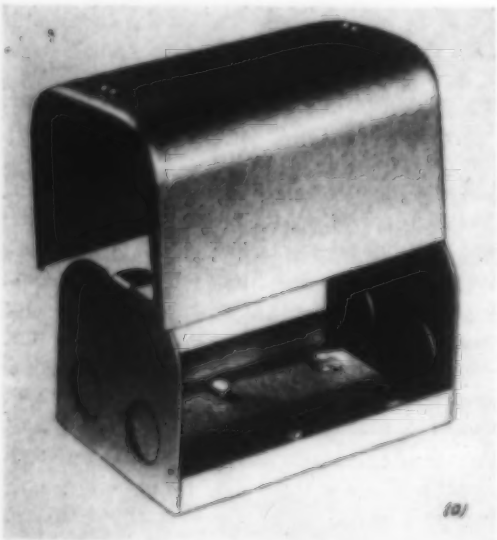


covers on these enclosures may be fastened with screws (*Fig. 9a*), snapped into place (*Fig. 9b*), or pushed on (*Fig.* 9*c*). Of course, there are the completely hermetically sealed type of enclosures mentioned previously. Certain types of sensitive relays and those having delicate adjustments should always be provided with an enclosure of some sort, if for no other reason than to eliminate the danger of damaging the relay during handling and wiring. The use of an individual cover for protection from dust and sand is quite obvious, and most types of relays may be supplied with either metal or plastic covers for this purpose.

Sometimes more than one relay may be mounted within a dust cover or a hermetically sealed enclosure, *Fig.* 3; this permits the use of a single set of terminals for connection to equipment wiring. Such a design may often be the means of saving a considerable amount of space in equipment and at the same time offer considerable simplification in wiring as well as service replacement. From a purely economical standpoint it is not generally recommended since the cost of such a combination unit will often equal or exceed that of the individual relays separately mounted and terminated. It is also quite obvious that a failure of one relay in a group of this type would mean replacement of the entire assembly instead of just a single relay.

For complete relay protection from severe atmospheric contamination or for high-altitude operation, as in military aircraft, it is essential that the relays be completely hermetically sealed. Most relay manufacturers are now able to furnish practically any type of relay they make in a hermetically sealed enclosure which is generally filled with an inert gas such as dry nitrogen. Contrary to popular belief the complete physical protection of a relay by this means seldom contributes to improvement in useful service life of the relay.

Fig. 8 — Relay designed with special contact-circuit terminal tabs for mounting on printed-circuit plate



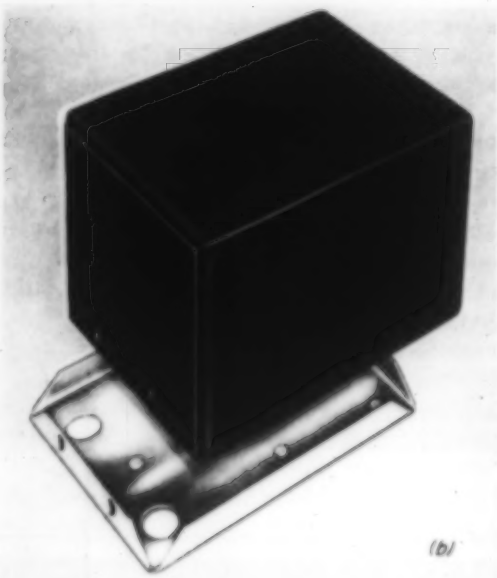
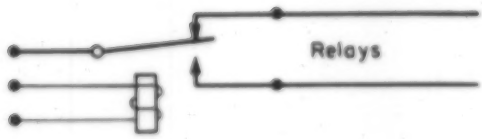


Fig. 9—Metal dust protectors for open type relays with covers fastened with machine screws (*a*), snapped into place (*b*), or pushed on (*c*)



In general, it has exactly the opposite effect, and a hermetically sealed relay will not provide as long life under the same load conditions as one without an enclosure of any sort. The reason for this is that the atmosphere within the relay enclosure is confined in a small space and becomes contaminated within a relatively short time with vaporization products of various materials used in the construction of the relay. A great deal of work is being done to eliminate this highly objectionable feature, but the results have not been completely satisfactory to date. The use of special magnet wire having completely inert insulation and the complete elimination of all possibilities of internal contamination result in an extremely costly relay and can only be justified in very critical applications. Thus, a hermetically sealed relay should be used only where required by high-altitude or extremely adverse atmospheric conditions. In other types of applications better results will generally be obtained by using either an open relay or one with a simple dust cover.

Finishes: Other physical-requirement relay features might include the type of finish used on the metal parts of the relay or on the external enclosure. Unless special reasons exist, it is usually not necessary to specify certain types of plating on relay parts since this will be taken care of in the design of the relay after performance requirements as well as environmental conditions have been thoroughly evaluated. With respect to external container finish, most manufacturers have standard materials and colors with variations usually available at slight extra cost. Here again, the selection of a suitable finish to best resist the effect of moisture, humidity or corrosive atmosphere may best be made by the relay manufacturer when complete information on these aspects of the application is provided.

Markings: Usually, marking of open or unenclosed relays is limited to the relay manufacturer's name or trade mark and his part number as shown in *Fig.* 4 or with the possible addition of the equipment manufacturer's designation, *Fig.* 7*d*. On most of the smaller type relays there is seldom room for any more than this limited amount of information. Actually there isn't any particular need for anything else on open type relays, since the terminals are all exposed and the wiring connections are quite evident from physical examination of the relay. On enclosed units, however, it is common practice to add a simple diagram of the wiring connections, together with any additional data that may be required by the equipment manufacturer or by military specifications controlling this phase.

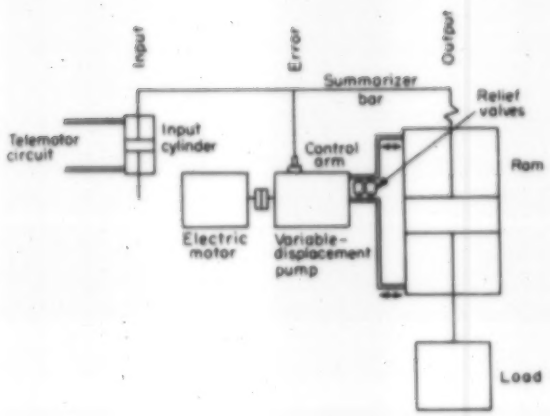


Fig. 1—Conventional hydraulic servo practice is to use a variable-displacement pump. Pump pressure adjusts to match load requirements. Either radial or axial piston type pumps may be used

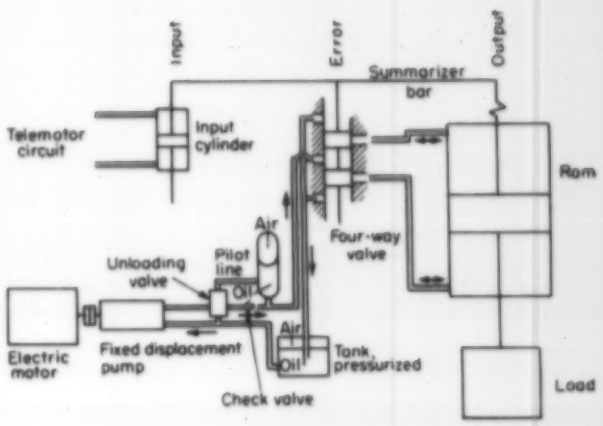


Fig. 2—Hydraulic servos using fixed-displacement pumps may be constructed using an accumulator to provide a nearly constant system pressure. When large flow is delivered against moderate load, excessive power is dissipated in the four-way valve. Under such conditions, cooling equipment is usually needed to limit hydraulic oil temperature

Applying fixed-displacement pumps to

Variable-Pressure Hydraulic Servomechanisms

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. . . can often lead to reduced size and cost in the multihorsepower range. Internal and external bypassing systems offer a choice of design criteria

WITH hydraulic servos at the multihorsepower level, power dissipation and oil heating considerations usually dictate the choice of a system that adjusts the pump pressure to the requirements of the load. This is readily accomplished through the use of a variable-displacement pump of either the radial or axial piston type, *Fig.* 1. The pump develops sufficient pressure to deliver a flow which is proportional to servo error and also develops a differential pressure in the steady or zero flow state dependent upon torque load at the ram. However, variable-displacement pumps are costly and excessively large compared to fixed-displacement pumps, and it would be desirable to incorporate the latter type pump in a variable-pressure servo.

Ordinarily, a fixed-displacement pump would be used in a nearly constant-pressure system, *Fig.* 2. Here the pump delivers oil to an accumulator. When the accumulator pressure reaches a predetermined high value, the unloading valve bypasses the pump at negligible pressure and the check valve isolates the pump from the remainder of the system. The load is then supplied from the accumulator and when the accumulator pressure drops to a predetermined low, the unloading valve closes the bypass path and the pump de-

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livers oil to the accumulator again under pressure. The integrating device is an overlapped four-way valve. Since excessive power is dissipated in the four-way valve when the valve is delivering a large flow against a moderate load, this system often is not satisfactory. Cooling equipment is usually required to limit the maximum oil temperature to a reasonable value.

Variable-Pressure, External-Bypassing Servo: A servo using a fixed - displacement pump, *Fig.* 3 has been developed for a 15-hp, high-performance, U. S. Navy application and is in successful operation. The system proportions load flow as a function of servo error independently of the torque load at the ram and at the same time continuously and smoothly adjusts the pump pressure to the requirements of the load in the transient and steady states.

Nomenclature

A_B = Port area of bypass metering valve
A_L = Total port area of load metering valve
C_1 = Constant
$= (Q_L/2KH)^2$
C_2 = Constant = pressure drop across four-way valve of external-bypassing servo when $X = 0$.
$= 2\,C_1/U_2 = (Q_L/KHU)^2/2$
C_D = Orifice discharge coefficient
g = Acceleration due to gravity
H = Port height of four-way valve
H_B = Port height of bypass metering valve
H_L = Port height of load metering valve
K = Constant
$= C_D \sqrt{2g/W}$
P_1, P_2 = Pressures in ram lines
P_S = Pump supply pressure (over drain pressure)
P_W = "Wasted" pressure
$= P_S - (\Delta P)$
ΔP = Differential pressure across ram lines
$\Delta P_1, \Delta P_3$ = Pressure drops across supply orifices of four-way valve
$\Delta P_2, \Delta P_4$ = Pressure drops across return orifices of four-way valves
ΔP_L = Pressure drop across load metering valve
Q_B = Flow through bypass metering valve
Q_L = Flow through load metering valve (flow into ram when $X \geq U$)
Q_M = Flow into ram (internal-bypassing servo)
Q_P = Pump flow
U = Underlap at faces of four-way valve spools
U_B = Zero error port opening of bypass metering valve ($U_B >> U$)
U_L = Underlap at each face of load metering valve spool
W = Specific weight of fluid flowing
X = Servo error or error displacement of load metering valve (external-bypassing servo) and four-way valve (external and internal-bypassing servos)
y = Output motion of bypass metering valve operating mechanism
$= |X|$
Y = Nondimensional error displacement
$= X/U$

Flow Ratio Action: The flow ratio controller[1] in the error channel consists of a load metering valve (single spool underlapped at both faces) which meters the load flow, a bypass metering valve (single spool metering at one spool edge only) which meters the bypass flow, and a floating throttle valve which throttles the bypass flow. The pump flow is divided between the two metering valves. The four-way spools (underlapped at all four faces) have only a directional function in the servo.

The floating throttle valve senses the pressures downstream of the load metering and bypass metering valves. If these pressures are not equal, the valve piston will move, thereby either increasing or decreasing the throttling port area of the valve, to establish the pressure downstream of the bypass metering valve equal to the pressure downstream of the load metering valve. Since the two metering valves are "teed" together upstream, the pressure drops across the two valves will be equal in the equilibrium condition. The division of pump flow between the two metering valves will then be a function only of the ratio of the port areas of the two metering valves and so will be independent of the torque load at the ram. This relation is

$$\frac{Q_L}{Q_B} = \frac{A_L}{A_B} = \frac{H_L(U_L + X)}{H_B(U_B - X)} \qquad (1)$$

For $X \geq U_L$.

Sufficient pressure is developed by the pump to deliver the flow determined by the valve port area ratio against the torque load. It can be seen that the port area of the load metering valve increases for either direction of increasing servo error. The piston of the bypass metering valve is actuated by a mechanism which gives the same direction of output motion for either direction of input motion so that the port area of this valve decreases for either direction of increasing servo error. Thus from Equation 1 it can be seen that for increasing servo errors, more of the pump flow will be directed into the load metering valve and thence to the ram through the four-way valve and less of the pump flow will be bypassed. As the ram follows up and returns the pistons of the metering valves toward their zero error positions (decreasing servo error), less of the pump flow will be directed into the load metering valve and more of the pump flow will be bypassed. For servo errors exceeding the proportioning band (bypass metering valve port closed), all of the pump flow will be directed into the load metering valve and thence to the ram.

The variation of load flow with servo error may be derived from Equation 1 by neglecting U_L which is very small in practice and recognizing that $Q_P = Q_L + Q_B$. The expression is

[1]References are tabulated at end of article.

$$\frac{Q_L}{Q_P} = \frac{1}{\frac{H_B}{H_L}\left(\frac{U_B}{X} - 1\right) + 1} \quad \ldots\ldots (2)$$

It can be seen that for $X = U_B$ (bypass metering valve port closed), the load flow is equal to the pump flow as mentioned before so that the proportioning band can be varied by adjusting the zero error opening of the bypass metering valve. For the case of $H_B = H_L$, Equation 2 reduces to

$$Q_L = \left(\frac{Q_P}{U_B}\right) X \quad \ldots\ldots (3)$$

so that for this case load flow is a linear function of servo error. For $H_B/H_L > 1$ or $H_B/H_L < 1$, the speed vs. error characteristic will be nonlinear, *Fig.* 4.

The secondary flow into the bypass throttling valve which accompanies movements of the valve piston tends to create a premature, temporary equalization of pressures downstream of the load metering and bypass metering valves. For this reason, the volumetric displacement of the bypass throttling valve should be made as small as possible for good dynamic response of the servo.

STEADY STATE PRESSURE CONSIDERATIONS: In the steady state (ram stopped), almost all of the pump flow is directed into the bypass metering valve and thence to the bypass throttling valve. Only a small fraction of the pump flow leaks around the underlapped load metering and four-way valve spools. For zero torque load at the ram, the load metering valve and four-way valve spools will be exactly centered about their ports and the pump pressure will be at a minimum. Good design keeps this minimum pressure at a negligibly small value. The differential pressure across the ram lines will be zero for zero torque load.

If a torque load is applied at the ram, a small movement will be transmitted to the load metering and four-way valve spools which will then tend to take up a new position within the underlapped range of the four-way valve. The resistance of the four-way valve spools to the leakage flow is thereby increased and the pressure downstream of the load metering valve tends to increase. This

Fig. 3—A successful variable-pressure external-bypassing servo using a fixed-displacement pump continuously and smoothly adjusts pump pressure to load requirement. Developing 15 hp, the servo is used in a U. S. Navy application

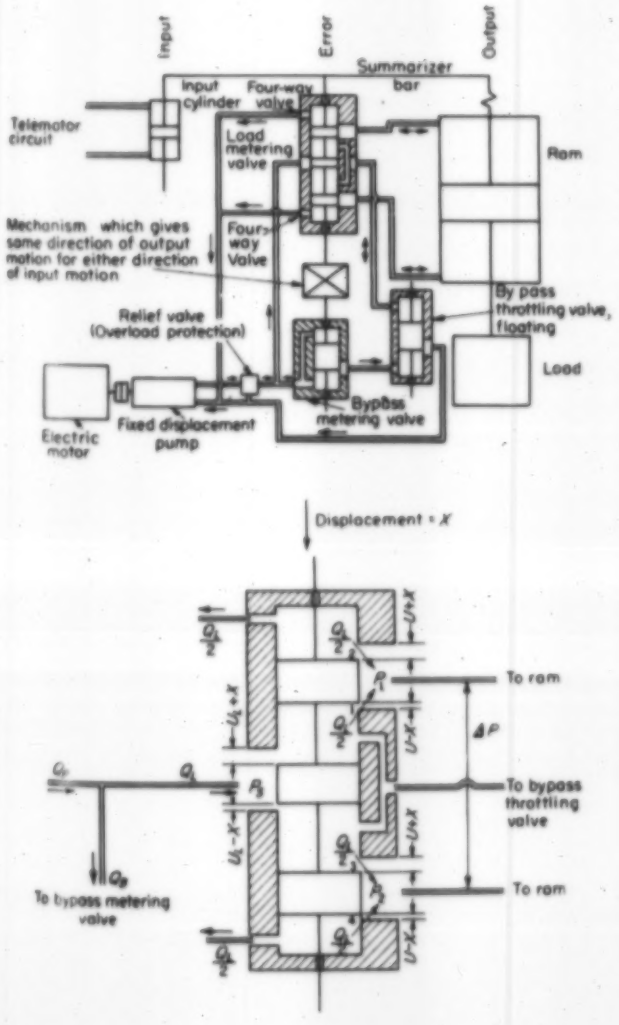
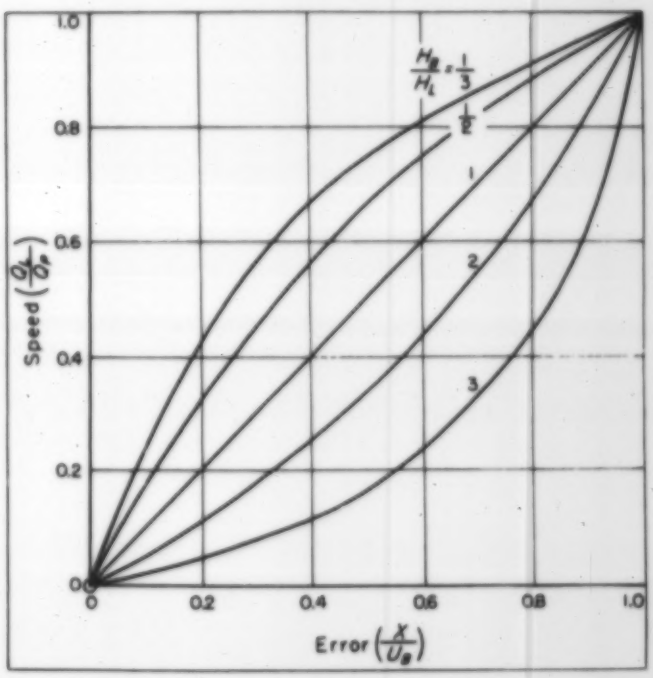


Fig. 4—Speed-error characteristics of the variable-pressure, external-bypassing servo for any ram load



causes the bypass throttling valve to float toward its closed position, thereby increasing the throttling of the bypass oil. The piston of the throttling valve will be stopped when the pressure downstream of the bypass metering valve is equal to the pressure downstream of the load metering valve. The pump supply pressure thus is increased and this increased pressure in conjunction with the error displacement of the four-way valve spools will develop a differential pressure across the ram sufficient to hold it against the torque load.

If the four-way valve spools are moved by an amount equal to their underlap, the leakage flow through the load metering and four-way valves will be cut off. The pressure downstream of the load metering valve will therefore rise to the pump supply pressure. This will cause the floating throttle valve to close entirely, thus cutting off the bypass flow and raising the pressure downstream of the bypass metering valve to the pump supply pressure. The only path left to the pump flow then is the relief valve which is set slightly above the highest pressure required by the system for the peak load condition. Thus the dead zone of the servo cannot exceed the underlap of the four-way valve spools. With small underlap (U is usually of the order of 1/30 U_B), resolutions of the order of 1/500 of total output can easily be obtained.

Equations for pump supply pressure, P_S, differential pressure across the ram lines, ΔP, and "wasted" pressure, P_W, as functions of valve displacement (ram stopped) within the underlapped region of the four-way valve are

$$P_s = \left(\frac{Q_L}{2KH_L U_L}\right)^2 + \frac{1}{2}\left(\frac{Q_L}{KHU}\right)^2 \frac{1+\left(\frac{X}{U}\right)^2}{\left[1-\left(\frac{X}{U}\right)^2\right]^2}$$

$$= \Delta P_L + C_2 \frac{1+Y^2}{(1-Y^2)^2} \qquad (4)$$

$$\Delta P = \left(\frac{Q_L}{KHU}\right)^2 \frac{\left(\frac{X}{U}\right)}{\left[1-\left(\frac{X}{U}\right)^2\right]^2} = \frac{2C_2 Y}{(1-Y^2)^2} \qquad (5)$$

$$P_w = \left(\frac{Q_L}{2KH_L U_L}\right)^2 + \frac{1}{2}\left(\frac{Q_L}{KHU}\right)^2 \frac{1}{\left(1+\frac{X}{U}\right)^2}$$

$$= \Delta P_L + \frac{C_2}{(1+Y)^2} \qquad (6)$$

where, Q_L is considered constant and

$$\Delta P_L = \left(\frac{Q_L}{2KH_L U_L}\right)^2$$

$$C_2 = \frac{1}{2}\left(\frac{Q_L}{KHU}\right)^2$$

In the derivation of these equations, it is assumed that $U_L \geqq U$ and $U_B >> U_L$. Therefore, A_L is constant when $X \leqq U$ and A_B and Q_L may be considered constant when $X \leqq U$.

These equations are plotted in *Fig. 5*. By proper sizing of the metering valves, ΔP_L and C_2 will be small and the steady state pump supply pressure will very nearly be equal to the differential pres-

Fig. 5—Supply pressure, differential pressure, and "wasted" pressure, when $\Delta P_L = 4C_2$, as functions of valve displacement within underlapped range of four-way valve (ram stopped). Pressure is expressed in terms of the drop across the valve

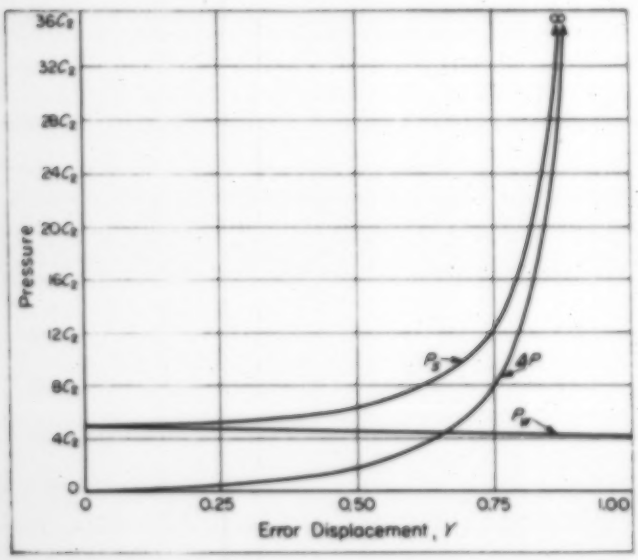
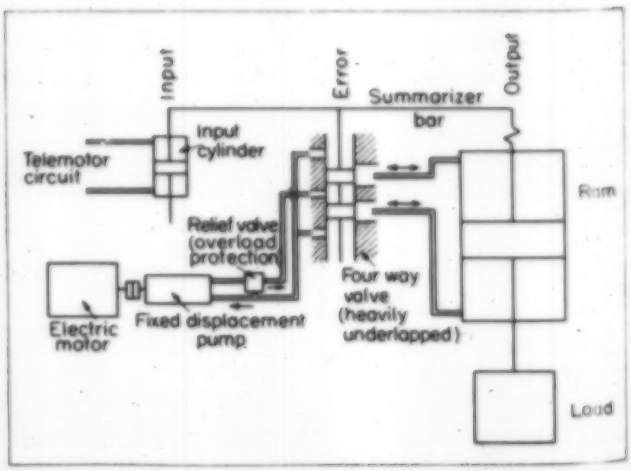


Fig. 6—Considerable simplification in the circuitry of a variable-pressure servo using a fixed-displacement pump is obtained by using an internal-bypassing, four-way valve. However, this servo does not equal the external-bypassing servo in static accuracy or dynamic performance



sure required by the torque load at the ram. Thus P_w will be negligible.

Variable-Pressure, Internal-Bypassing Servo: A more simple solution to the problem of incorporating a fixed-displacement pump in a variable-pressure servo is arrived at by internal bypassing within the four-way valve, *Fig.* 6. This eliminates load metering, bypass metering, and floating throttle valves. However, simplicity is acquired at a considerable sacrifice of static accuracy and dynamic performance.

All four spool faces of the four-way valve are very heavily and equally underlapped. When the valve spools are centered about the ports (zero torque load at ram), the pump flow will bypass around the spools at a very low pressure. This pressure is kept low by making the port height and spool underlap suitably large. When the spools are centered, the differential pressure across the ram lines is zero. Variation of pump supply pressure, differential pressure across the ram lines, and "wasted" pressure as functions of valve displacement (ram stopped) within the underlapped range are given by the same equations as for the external-bypassing servo except that ΔP_L drops out and Q_L is replaced by Q_P. The equations are

$$P_s = \frac{1}{2}\left(\frac{Q_P}{KHU}\right)^2 \frac{\left[1+\left(\frac{X}{U}\right)^2\right]}{\left[1-\left(\frac{X}{U}\right)^2\right]^2} \quad \text{.....(7)}$$

$$\Delta P = \left(\frac{Q_P}{KHU}\right)^2 \frac{\left(\frac{X}{U}\right)}{\left[1-\left(\frac{X}{U}\right)^2\right]^2} \quad \text{.....(8)}$$

$$P_w = \frac{1}{2}\left(\frac{Q_P}{KHU}\right)^2 \frac{1}{\left(1+\frac{X}{U}\right)^2} \quad \text{.....(9)}$$

Steady-state errors up to the four-way valve underlap will exist, as for the external-bypassing servo, depending upon the steady-state torque load. These errors, however, will be large since the underlap must be made large to provide adequate bypass area. Bypassing is accomplished, it will be remembered, in a separate valve in the external-bypassing servo. Pump flow is divided between the valve leakage path and ram in the transient state for valve piston displacements less than the underlap and all of the pump flow is delivered to the ram when the underlap (bypass path) is closed off. The actual flow proportioning band will thus depend upon the steady state valve position and therefore the steady state torque load. Also, for each value of torque load other than zero, the flow proportioning bands in the positive and negative error directions will be different. A serious stability problem may exist, therefore, for one direction of error signal for large torque loads. Dynamic performance and static accuracy of the system will thus vary widely with torque load and such a system is satisfactory in relatively few applications.

The differential pressure versus ram flow characteristic for this type of valve has been developed by Blackburn.[2] In the nomenclature of this article, the equation is

$$\frac{\Delta P}{\left(\frac{Q_P}{KHU}\right)^2}\left[1-\left(\frac{X}{U}\right)^2\right]^2 = \frac{X}{U}\left(\frac{Q_M}{Q_P}\right)^2 - \left[1+\left(\frac{X}{U}\right)^2\right]\left(\frac{Q_M}{Q_P}\right)+\frac{X}{U} \quad \text{.....(10)}$$

Characteristics of the valve have been shown to be very nonlinear.

Summary: Various solutions to the problem of providing a variable-pressure hydraulic servo exist. A servo which adjusts the pump supply pressure to the requirements of the load is desirable at higher horsepower levels as a means of minimizing power dissipation and oil heating effects. The most simple variable-pressure servo uses a variable-displacement pump. However, from the standpoint of cost and compactness, a fixed-displacement pump is a more logical choice as the source of hydraulic power.

The most commonly used fixed-displacement pump servo employs a four-way control valve supplied at nearly constant pressure. This system is wasteful of power when delivering large flows against moderate loads and oil cooling equipment is often required. The two variable-pressure, fixed-displacement pump servos discussed in this article, overcome this drawback. The external bypassing servo should be the most useful of the two. However, the internal-bypassing servo offers considerable simplification in valving.

Acknowledgement

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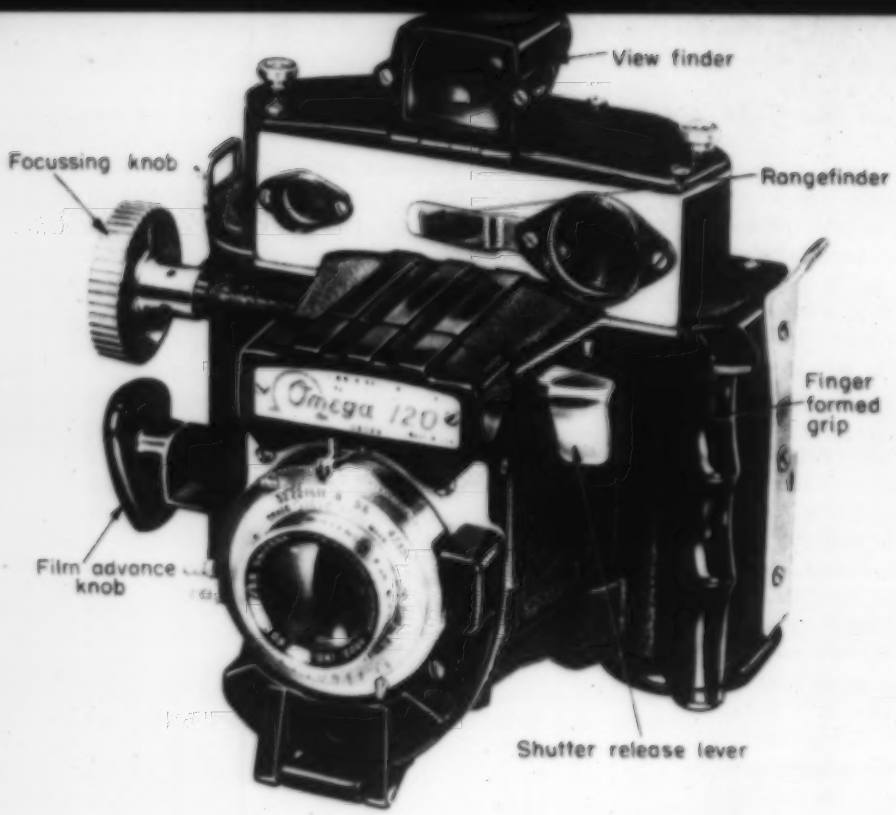
1. A. H. Dall—"Machine Hydraulics," MACHINE DESIGN, Vol. 18, No. 6, June, 1946. Page 111.
2. J. F. Blackburn—"Contributions to Hydraulic Control—3," *ASME Trans.*, Vol. 75, No. 6, August, 1953. Page 1163.

"He (the engineer) must not compromise with the truth, but must realize that compromises are always necessary if anything really worthwhile is to be accomplished in business, politics or a happy marriage. Black is not black, and white is not white in these areas.

"He will find a sense of humor invaluable, so that he will take his work seriously, but not himself.

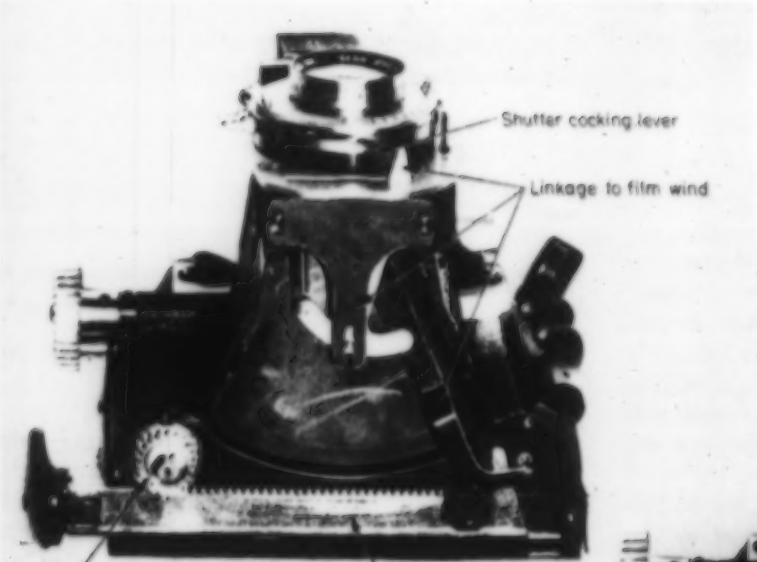
"He must have charity and patience with those who do not have the knowledge that he possesses.

"He must come out of his cell, which is too often walled by complete absorption in his work, and show interest and activity in civic and political affairs."—JOHN C. SHARP, *president, Hotpoint Co.*

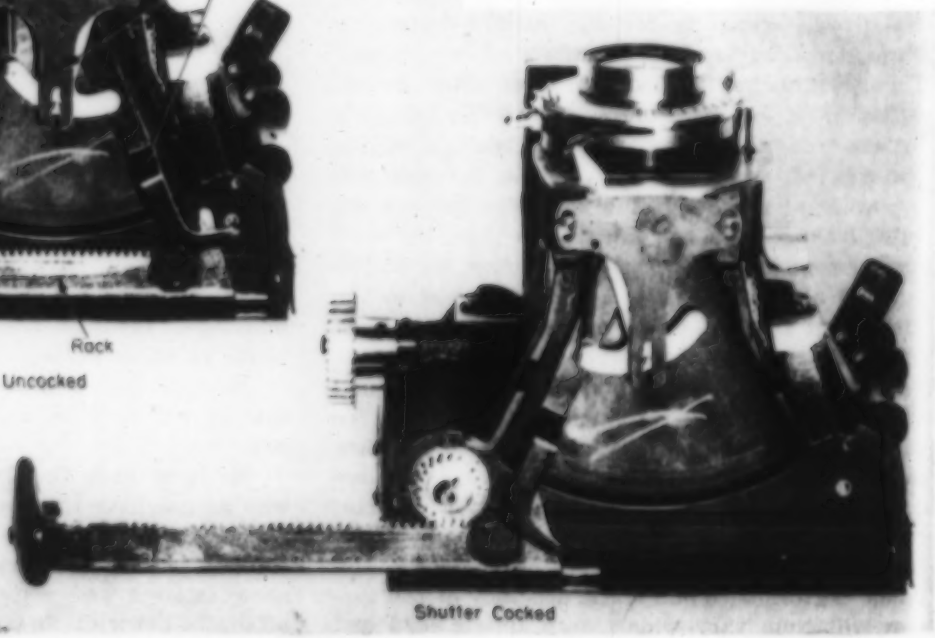


LARGE operating knobs, unique camera body shape and other features incorporated in a recently developed camera are all calculated to make picture taking easier for the camera user. Operation of the lens-coupled rangefinder automatically shifts the viewfinder to compensate for parallax. A rapid film-advance mechanism eliminates the usual watching for a number through a red window by automatically advancing the film the correct distance. Labelled the Omega 120, the camera is a product of Simmon Brothers Inc.

CAMERA DESIGNED FOR

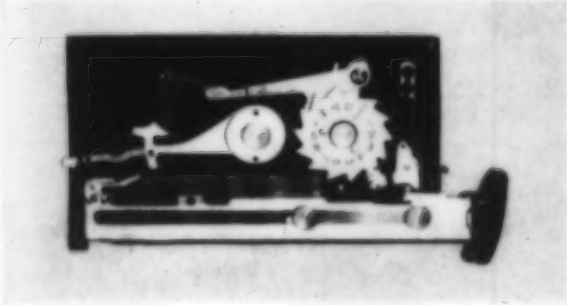


Rapid film-advance mechanism consists primarily of a rack and pinion coupled to the film spool by an overrunning clutch. Withdrawal and return stroke of the rack advances the film the correct distance and at the same time cocks the shutter.



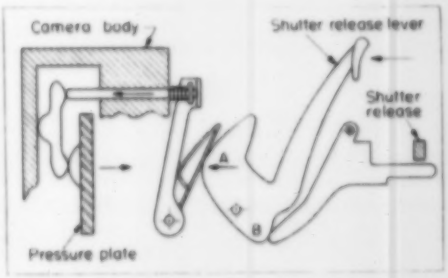
Contemporary Design

Automatic exposure counter is also coupled to the film wind rack. A ratchet and pawl are used to indicate the number of the exposure through a window in the back of the camera. An interlock prevents removal of the camera back until all exposures have been made.

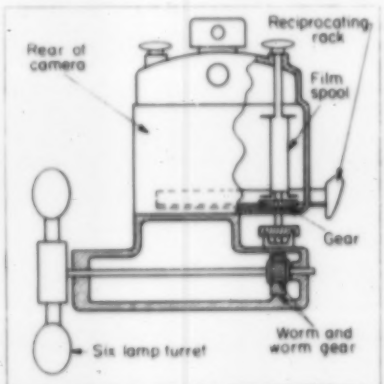


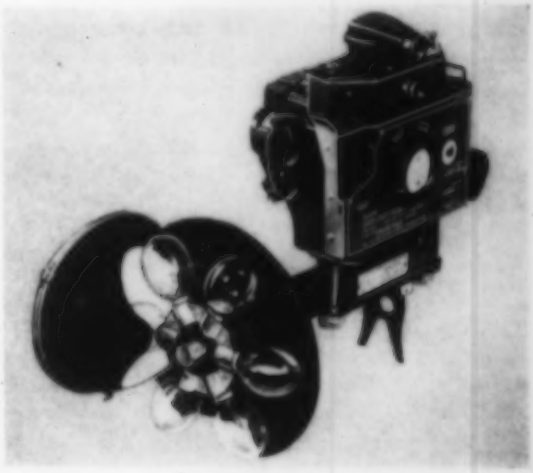
EASY HANDLING

Pressure plate, which holds the film in the focal plane during exposure, is an accurately ground ceramic material. To assure absolute flatness of the film and prevent scratching the film during winding, the pressure plate contacts the film only during the actual exposure. Because of this feature, much higher pressure than is usual can be used to assure film flatness. As the shutter release is pressed, cam **A** on the shutter-release lever forces the pressure plate into contact with the film through an intermediate linkage. Continued movement of the release lever causes cam **B** to actuate the shutter tripping mechanism.



Automatic flash - bulb turrets which couple to the film-wind mechanism are made for use with the camera. Each turret holds six bayonet-base flashbulbs. Operation of the film-wind rack causes the turret to revolve 1/6-turn and position a fresh bulb in the reflector. Electrical contacts are also made at the same time.





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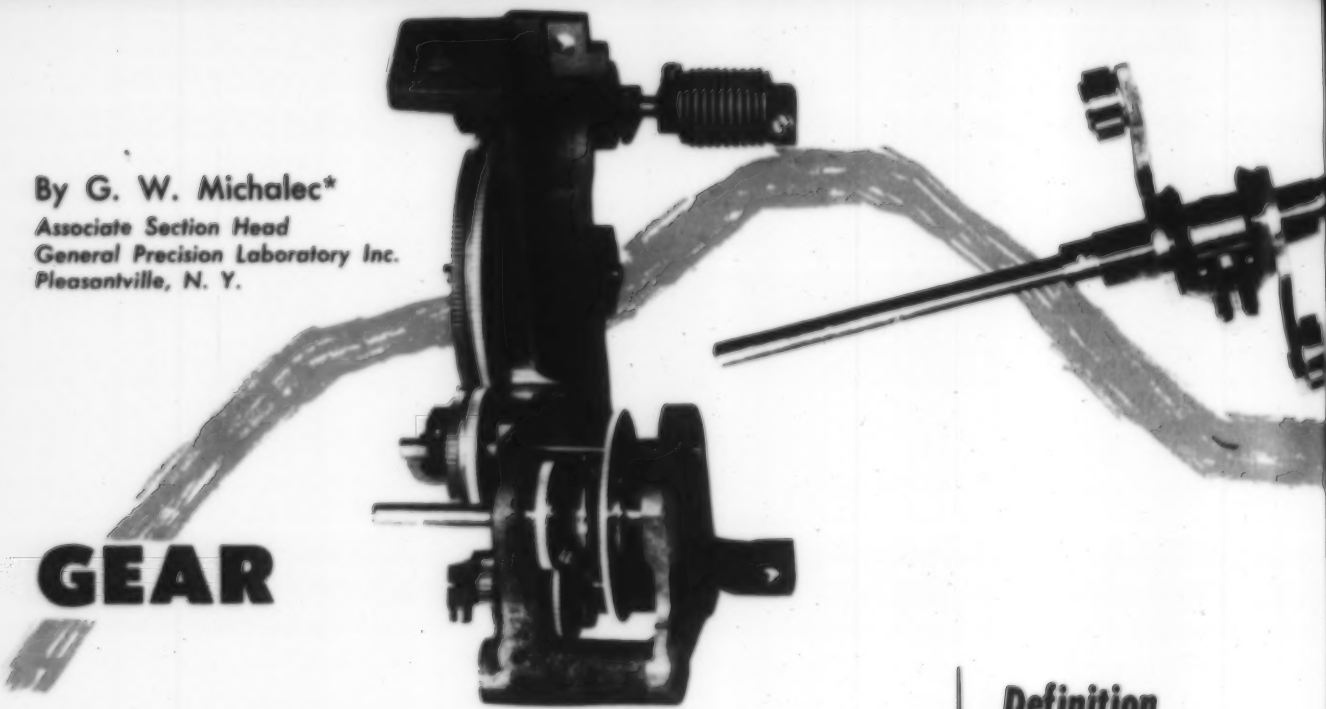

GEAR DIFFERENTIALS Part 1

Definition
Analysis
Types
Applications

ONE OF THE oldest applications of gear trains was the mechanical differential. Early in the study and development of kinematic mechanisms it was invented as a means of applying "difference" motion. Today, the mechanical differential is an important basic component of machine design. Its use in the rear end of millions of modern automobiles is familiar. It is also widely used for control and computing applications. In fact, the mechanical differential is still the most accurate means for accomplishing addition and subtraction in electromechanical computing devices. Other applications, such as torque measuring, clutches, brakes, etc., add to its importance.

Functional definition of the differential taken from its most widely used applications is: a mechanism which does angular addition or subtraction, having two shaft inputs, and delivering the answer on a third shaft. Furthermore, it will add or subtract any number of revolutions or fractions of a single revolution, and can do this continuously. Therefore, as the inputs change, it will deliver a continuous answer.

When the unit performing this function is composed of mechanical elements such as gears, gears and a rack, disks or balls and plane surfaces, or linkages, the mechanism is known as a *mechanical* differential. This distinguishes it from electromechanical units, such as the differential synchro.

In particular, when the differential is of the gear design, it is a special type of epicyclic gear train. This will be shown more completely later. This article deals exclusively with the gear-type mechanical differential, hereafter simply called differential.

Basic action of a differential is seen in the motion of a cylinder rolling on two parallel surfaces.

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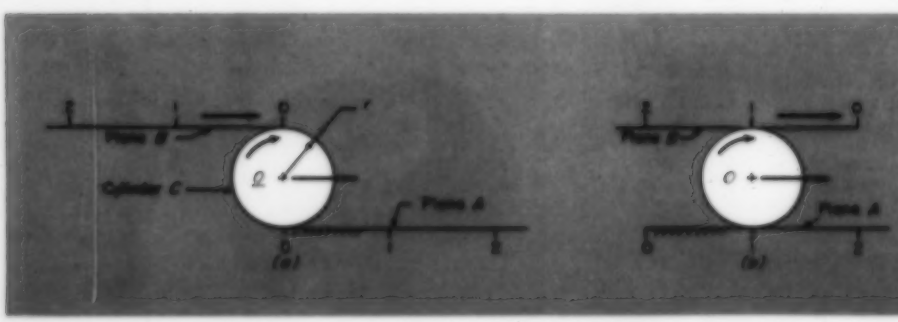


Fig. 1—Fundamental differential motion: a, initial position; b, position after cylinder has rolled unit distance on plane A

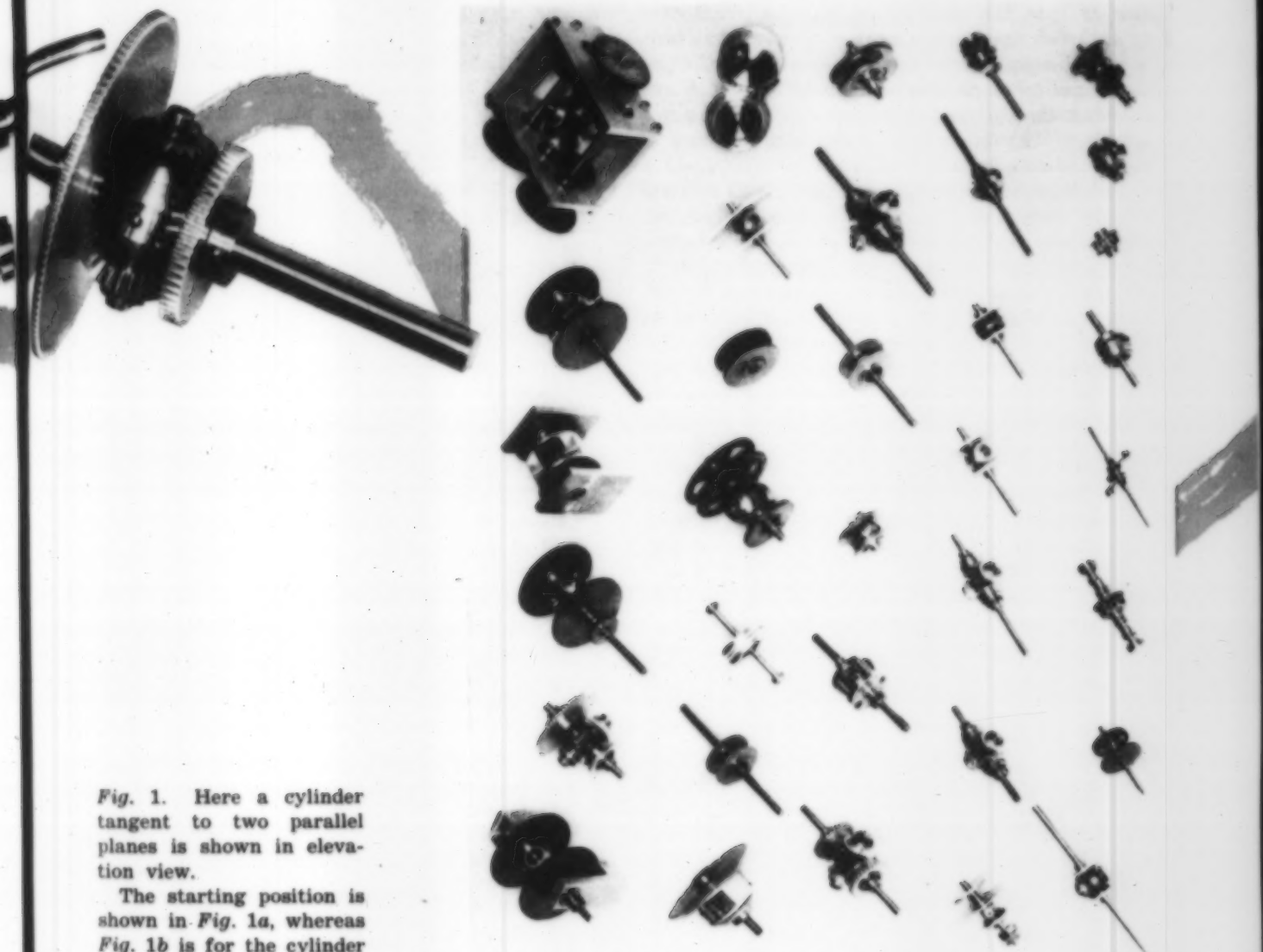
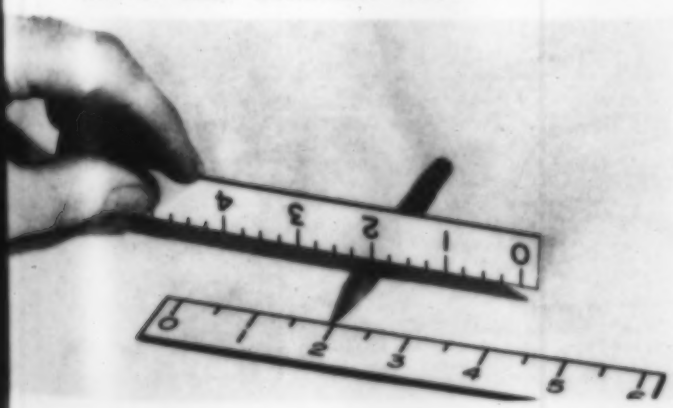


Fig. 1. Here a cylinder tangent to two parallel planes is shown in elevation view.

The starting position is shown in *Fig.* 1*a*, whereas *Fig.* 1*b* is for the cylinder advanced a unit distance. For the cylinder rolling a unit distance on the lower plane *A*, the upper plane *B* has also rolled 1 unit distance relative to the cylinder. However, the total distance traveled by plane *B* is 2 units distance. This is true because the displacement of plane *B* is equal to the displacement of point *O* (center of the cylinder) plus the relative displacement of *B* with respect to *O*. Or analyzing another way, the instantaneous center of rotation is the contact on plane *A*. Therefore, the velocity of point *O* and the point of tangency on plane *B* will be in the proportion 1:2 because their instantaneous radii are r and $2r$, where r is radius of the cylinder.

Fig. 2—Simple desk-top demonstration of basic differential motion



By extension of analogous reasoning, if plane *A* is also movable, the position of the cylinder will depend upon the relative magnitudes and sense of direction of the displacements of planes *A* and *B*. Obviously, if *A* and *B* have equal displacement, but opposite sense, the cylinder will rotate, but its center will be stationary. If they both move in the same direction with equal displacement, the cylinder will be carried and moved in the same sense and its total displacement will be the same as that of the two planes. When the planes have displacements that are opposite in sense, the displacement of the cylinder will be a function of the algebraic difference of their displacements.

Displacement of the cylinder is not equal to the full sum of the displacements of the planes *A* and *B*, but is one-half their vector sum. This was

also true in the example of *Fig.* 1*a*, transposed to 1*b*, when the displacement of plane *A* was zero. It is also equally true in the special case of equal and same sense of displacement of planes *A* and *B*. Then the cylinder is merely carried along and therefore its motion is still one-half the sum of the displacements *A* and *B*.

The displacement ratio of either plane and the cylinder center is a constant factor and therefore correctible, so it need not be of serious concern. Furthermore, it is interesting and important to note that the diameter of cylinder *C* is of no significance. Although the number of revolutions of cylinder *C* will be inversely proportional to its diameter for given displacements of *A* and *B*, the ratios of displacements between the three elements *A*, *B* and the center of *C* will always be the same regardless of the cylinder diameter.

Fundamental differential motion can be conveniently demonstrated with a pencil and two desk rulers. With the pencil being rolled on the desk with the edge of one ruler, displacement of the pencil and ruler can be measured relative to the second ruler placed on the desk top along the path of motion, *Fig.* 2. Insignificance of the diameter of the cylinder can be shown by substituting other cylindrical objects for the pencil.

Ratio of motion between planes and cylinder is known as internal gear ratio. It has already been shown to be a ratio of 2 for the basic elements, and as will be developed, this is the ratio for all simple differentials.

Bevel gear differential evolves logically from the cylinder and plane concept. Evidently, having a cylinder roll continuously between two planes is only possible if the planes are infinitely long. However, the procedure becomes practical if the planes are twisted into flat rings and the cylinder, reduced to a disk, rolls between them in a circular path, with its measure of displacement being the number of revolutions it moves around the plane rings, *Fig.* 3.

Cylinder *C*, rotating on axis *X-X*, is constrained to roll in a circular path about axis *Y-Y* and between the two rings *A* and *B*, representing planes *A* and *B* of *Fig.* 1. As in the case of rolling planes, the distance *C* rolls is one-half the vector sum of the distance the ring planes *A* and *B* are displaced. Since the displacement of cylinder *C* is now circular, it can be used as a measure of angular displacement, and the following vector equation can be written:

$$N_C = \frac{N_A + N_B}{2} \qquad (1)$$

where N_A, N_B and N_C are revolutions or any other convenient measure of angular displacement such as radians, rpm, etc. Note that N_C is a measure of the rotation of axis *X-X* about *Y-Y*.

This mechanism would perform satisfactorily except for the inevitable slippage under load.

Obvious solution to this malfunction is to make the surfaces with teeth, thus giving a positive mechanical drive. This is readily accomplished by

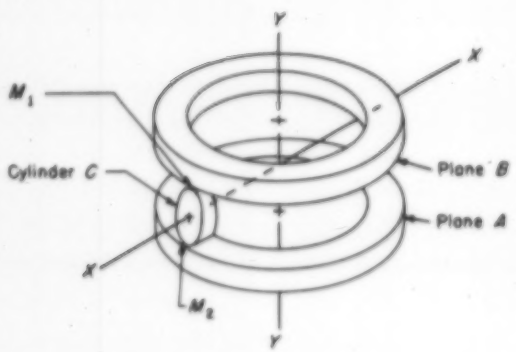


Fig. 3—Above—Evolution of planes into rings, with cylinder *C* reduced to a disk rolling between them in a circular path. Cylinder *C* rotates on axis *X-X* and is constrained so as to make axis *X-X* rotate about axis *Y-Y*

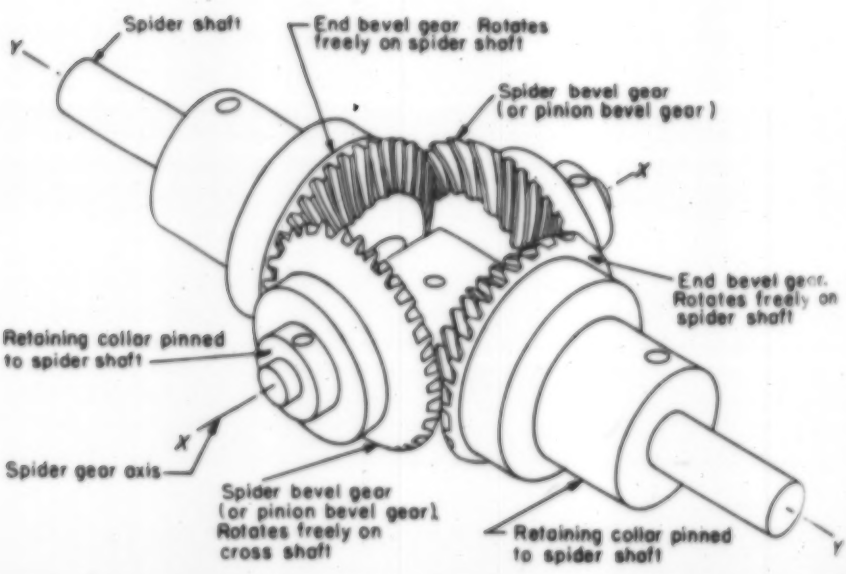

Spider shaft
End bevel gear Rotates freely on spider shaft
Y
Spider bevel gear (or pinion bevel gear)
X
End bevel gear. Rotates freely on spider shaft
Retaining collar pinned to spider shaft
X
Spider gear axis
Spider bevel gear (or pinion bevel gear) Rotates freely on cross shaft
Retaining collar pinned to spider shaft
Y

Fig. 4 — Right — Elements of a typical bevel gear differential evolved from rings and cylinder of *Fig.* 3

replacing the three elements with conjugate bevel gears, thus making the familiar bevel gear differential, *Fig.* 4.

In *Fig.* 4 the pinion bevel gear corresponds to the cylinder *C* of *Figs.* 1, 2 and 3. Note there are two such pinion bevel gears opposite each other which increase load capacity and provide dynamic balance for high-speed applications.

Also, *Fig.* 4 shows that the axis of the pinion bevel gears, and the axis about which this axis rotates forms a cross or, as it is commonly called, a spider. Therefore, the rotation of the spider shaft (axis *Y-Y* in *Fig.* 4) is an indication of the displacement of the pinion bevel gears.

Spur gear differential is perhaps less known than the bevel gear type because the latter is familiar as the drive transmission for the rear axle of automobiles. However, the spur gear differential is fundamentally the same even though it has a considerably different appearance.

This differential can be evolved from the original rolling cylinder and straight plane strips of *Fig.* 1, if the plane strips are visualized as rolled into short lengths of hollow cylinders with the cylinder *C* contacting their outside edges, *Fig.* 5.

It will be noted from *Fig.* 5*b* that if the centers of cylinders *A* and *B* are fixed, any displacement of either cylinder *A* or *B* will cause rotational displacement of cylinder *C* resulting in its loss of common contact with the two cylindrical surfaces of *A* and *B*. To correct this situation, cylinders *A* and *B* are made equal in diameter and concentric one above the other. The evolution of the final form of cylinder *C* is shown in *Fig.* 6. In the illustrations *Fig.* 6*a* is the same as *Fig.* 5*b*, and *Fig.* 6*b* is similar except cylinder *A* has been shifted slightly along the axis of *C* preparatory to rotating it concentric with cylinder *B* as shown in *Fig.* 6*c*. In order for cylinder *C* to remain in contact with cylinders *A* and *B* in going from *Fig.* 6*b* to 6*c*, it would be necessary to consider cylinder *C* pliable about its axis, much as a slender rubber cylinder, but torsionally rigid. Final arrangements of the elements and the distorted form of cylinder *C* are shown in *Fig.* 6*d*. Note that due to the U-bend in *C*, the rotations of the two legs will have opposite senses.

Now for a displacement of cylinder *A*, cylinder *C* will roll one-half this amount in the same direction. Therefore, the same displacement relationships established for the bevel elements apply to this unit. Thus, Equation 1 also defines the displacement relationships of this differential.

Obviously, distorting cylinder *C* into a U-shaped, torsionally rigid, but axially bendable rolling member is impractical. However, this is nicely overcome by slicing off the base of the U and maintaining proper motion and sense between the two disjointed legs of the U by moving them into contact with each other. Thus, *C* becomes two cylinders, C_1 and C_2, having a common contact and each also contacting one of the rolled-up planes.

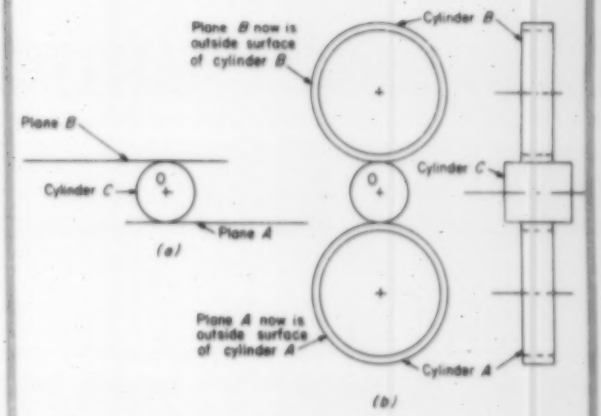


Fig. 5—Above—Evolution of basic differential elements, *a*, into hollow cylinders in rolling contact, *b*

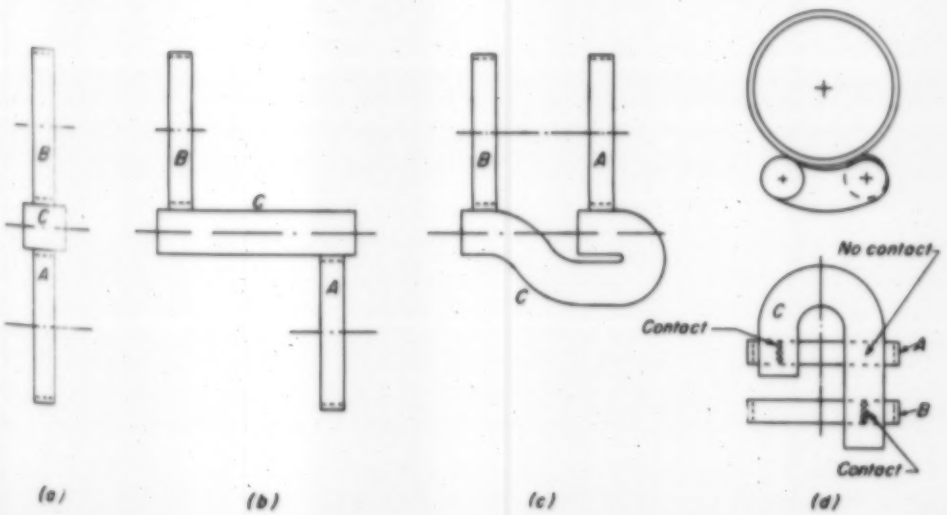


Fig. 6—Left—Further evolution of cylinders, *a*, to offset arrangement, *b*, and distortion of cylinder *C* as shown in *c* and *d*

A and *B*, *Fig.* 7.

Again, with gear teeth replacing friction surfaces, the differential takes the form shown in *Fig.* 8 which is the common spur gear differential.

The differential of *Fig.* 8 shows only one pair of spider gears (the *C* gears), but, for the same reasons bevel gear differentials have two spider gears, spur gear differentials are sometimes made with two or more pairs of spider gears. The terms "spider gear" and "spider shaft" are not as de-

Application 1—Addition and Subtraction of Shaft Positions or Speeds

This application of the basic differential function, *Fig.* 1.1, is the single most important one. It is widely used for this function in computers and controls, particularly in analog computers where differentials can conveniently perform arithmetical operations on the analog mechanical shaft parameters of positions and speed.

Addition and subtraction feature of the differential can be expanded into the following more specific applications:

Fig. 1.1 — Schematic of basic differential function

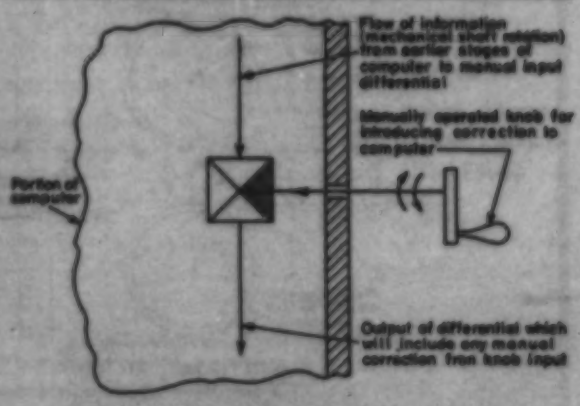

Flow of information (mechanical shaft rotation) from earlier stages of computer to manual input differential
Manually operated knob for introducing correction to computer
Portion of computer
Output of differential which will include any manual correction from knob input

Fig. 1.2—Schematic of differential application for manual inputs to a computer

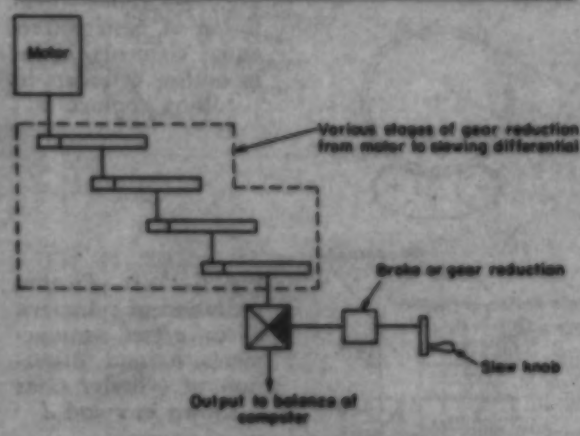

Motor
Various stages of gear reduction from motor to slewing differential
Brake or gear reduction
Slew knob
Output to balance of computer

Fig. 1.3—Schematic of application of a differential for zeroing or slewing of a gear train

Adding input data to a mechanism during its continuous operation. As an example, by this means the functioning of a computer can be corrected with manual or automatic setting-in data entered into one of the differential inputs, *Fig.* 1.2, without disrupting differential internal action.

Zeroing phases of a mechanical device. This use obviates either driving the entire mechanism or introducing slip clutches. An illustrative example is in the case of a load which is greatly geared down in speed from its driving motor. To position rapidly (slew) the load with a manual input at the load end of the gear train would require a large driving force since the reflected inertia of the high-speed end of the gear train would cause both large inertia and friction loads. However, by means of a differential inserted at the load end of the gear train, rapid and easy manual position of the load is possible, *Fig.* 1.3.

Locking the manual knob when not in use would be necessary to insure the drive acting upon the load. This would not be necessary if the load is insignificantly light and there is a gear reduction between the differential and manual knob. Then the output load side of the differential would offer the lesser resistance and the drive would be to it, with no danger of the drive acting in error upon the manual correction side of the differential.

Changing the phase relationship of a shaft in either a static or dynamic condition. A shaft which is geared through a differential can have its position altered, relative to its original position with other shafts, by means of an input to the differential. Since the differential is a continuously operating device, the phase changing can be done either with everything fixed or with the shaft rotating.

Altering the relative speed of a shaft. A known speed applied to one of the inputs will alter differential output speed. This is analogous to the application for shaft phase change, but instead of angular position, speed is the comparison.

By means of a differential and a controlled bidirectional variable-speed source, the speed of a prime shaft can be varied over a range from zero to a maximum value equal to the sum of the prime shaft speed and the maximum control input speed. This occurs because the differential adds vectorially, and with capability of reversing rotation of the differential output by reversing direction of the control input speed shaft. If speed range of the controlled bidirectional variable-speed source is greater than prime shaft speed, speed range can be controlled continuously from negative to positive values.

scriptive in this application as in the bevel gear differential. In *Fig.* 8, there is no spider shaft take-off but instead a spider gear take-off. There are spider pinion gears which together with the output spider take-off gear, end plates, and shafting constitute the spider housing assembly. However, there is no "spider" or "cross" of shafts in this unit. Nevertheless, these terms are used although they are not very applicable.

Again, the displacement of cylinder *C* or the spider gears is measured in terms of rotation of the *C* gears, and the displacements of planes *A* and *B* are measured by the rotation of gears *A* and *B*. Further, note that by rotation of *C* gears is meant their axle rotation about the common axes of gears *A* and *B*. In *Fig.* 8, rotation of gear *S* is a measure of this, since it is part of the "spider" construction which carries the *C* gears. Also, as with the bevel gear differential, the size of the *C* spider gears is irrevelant.

Internal gear differential can be evolved by referring to the original figure of the hollow cylinders (*Fig.* 5*b*). It is interesting to note that the cylinder *C* could have just as well contacted rolled-up planes *A* and *B* on the inside. The developed result woud be an internal spur gear differential, such as shown in *Fig.* 9. The intermediate evolutionary steps from starting with the basic elements are omitted since they are analogous to those of the external spur gear differential. An exploded view of an internal gear differential is shown in *Fig.* 10.

Differentials are epicyclic since a differential gear train involves gears whose axes are not fixed relative to other gear axes. Therefore, analogous analyses to those presented can be made by applying fundamental kinematic rules and procedures for epicyclic gear trains. However, the foregoing descriptive analysis seems easier to comprehend and to relate physically with the functioning of the differential.

Linear differentials go back to the original concept of a cylinder rolling between two straight planes, as pictured in *Fig.* 1. They are applicable to cases where linear motions are to be added or subtracted. The planes become gear racks and the cylinder again a spur gear, *Fig.* 11. Of course, to make a practical device, consideration must be given to proper design of bearing supports and guides for the racks, and a support and take-off for the spider gear.

Other differentials have also been developed. So far, the analysis has been confined to gear differentials which add and subtract motions, but have a constant displacement ratio of 2:1 between the end gears and the spider gear. Or, stated another way, the internal ratio of these differentials is 2. However, differentials can be designed which have other ratios. In fact, theoretically, any ratio can be obtained. Differentials having internal

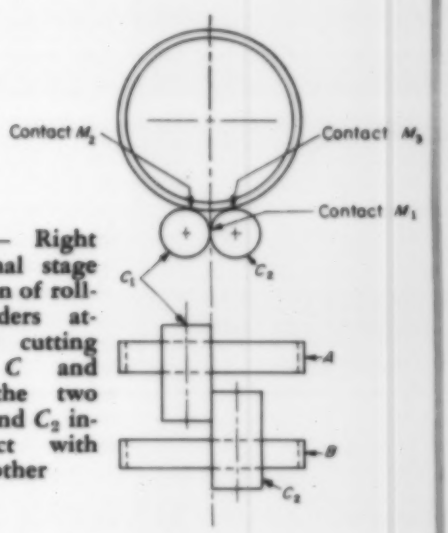


Fig. 7 — Right above—Final stage of evolution of rolling cylinders attained by cutting cylinder *C* and moving the two parts, C_1 and C_2 into contact with each other

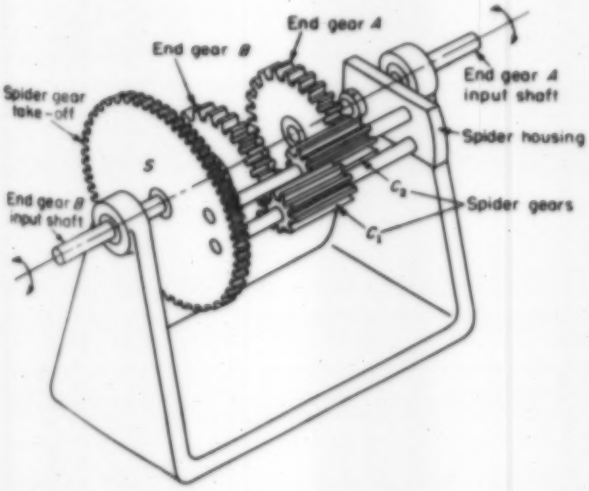


Fig. 8—Left—Elements of a typical spur gear differential evolved from the rolling cylinders of *Fig.* 7

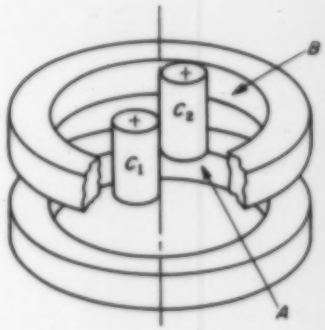


Fig. 9—Right—Essential elements of an internal spur gear differential, with cylinders C_1 and C_2 contacting cylinders *A* and *B* on the inside

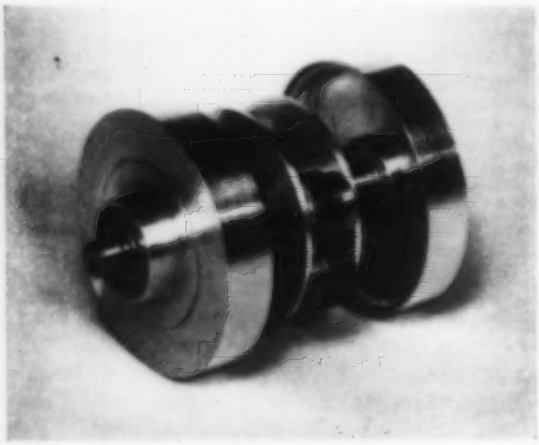


Fig. 10—Exploded view of an internal gear differential

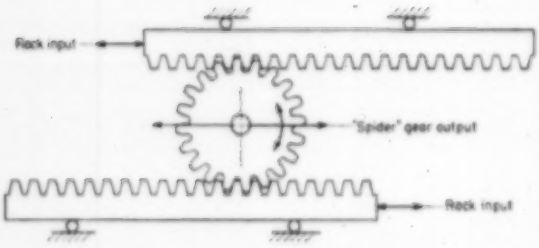


Fig. 11—Linear differential employing racks and a gear

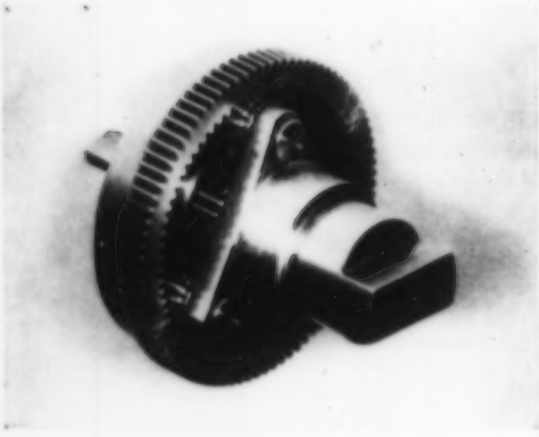


Fig. 12—Example of a gear differential having an internal ratio other than 2:1, known as a nonconformal or higher-ratio differential

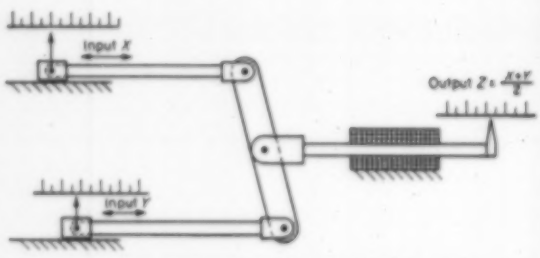


Fig. 13—Simple linkage differential

ratios other than 2:1 are considered special or nonconformal and therefore are called higher-ratio differentials.

Generally speaking, their design requires end gears of unlike diameters. Many are designed with an internal gear as one end gear. An example of such a differential is shown in *Fig.* 12. In this unit the ratio from end gear to end gear is 2:1 and end gear to spider gear 1½:1 and 3:1.

Nature and analysis of nonconformal differentials are similar to the previous examples, but slightly more involved. However, the majority of differential designs are of the common 2:1 internal ratio.

In addition to the gear differentials mentioned so far, there are other mechanical differentials which do not contain gear elements. For instance, there are linkage differentials such as the one shown schematically in *Fig.* 13, and screw differentials as shown in *Fig.* 14. Although their functioning is similar, no effort will be made to describe and analyze them here, since this article is limited to the more widely used gear-type mechanical differentials.

End gear take-offs are a means of transmitting motion to and from differentials.

In its simplified form the differential merely consists of two concentric rotating planes or cylinders with appropriate spider gears coupling them. This was shown in *Figs.* 3, 7, and 9. For practicality convenient means must be provided to put in and take off motion from the concentric members, or end gears as they have been called, and the spider gears.

With bevel gear differentials, end gear inputs or outputs are easily accomplished by making the end gear also part of a spur gear, or as often occurs in practice, an input spur gear is pressed, staked or otherwise fastened to a hub extension of the end bevel gear. These auxiliary end gears providing means for input and output are commonly called take-off gears. A simplified sketch of a bevel gear differential with end gear take-offs is shown in *Fig.* 15*a*. In *Fig.* 16 a differential is shown before and after the addition of end take-off gears. The end bevel and take-off spur gears are seldom fabricated integral because of the difficulty and the high cost. Furthermore, by making independent designs of the two elements, it is possible to replace the input end spur gears and so increase versatility of the differential. Bevel gear differential spider gear motion is coupled in or out by merely fastening a spur gear to the spider shaft, *Fig.* 15*a*.

In discussion of differential input and output gears, these terms are used interchangeably and often in a general sense. That is whether a specific end gear is an input or output will depend upon the application. Therefore, it is more appropriate to use the less specific term take-off.

Application 2—Dynamometer Torque Measurement

In this application, *Fig.* 2.1, the differential is inserted into a rotating mechanical shaft system at the point where the torque is to be measured. Essentially, the differential acts as a fixed gear train, the spider gears being stationary, and the input coming into one end gear and going out the other. Since the torque transmitted reacts against the fixed spider gears, this affords a means of measuring the torque.

The torque measurement is accomplished by having the spider housing react against a calibrated restraint, such as a torsion or extension spring as shown in *Fig.* 2.2. Using the internal reaction as a measure of torque requires that the differential internal gear and bearing friction be negligible, compared to the torque being measured.

A feature of this type of torque meter is that it conveniently lends itself to both static and dynamic operation. The differential is a rotating device and when properly designed can be operated at high speeds. Thus, a continuous torque check can be made from break-away or zero speed to the highest speed of operation.

A convenient way to make a torque dynamometer of the differential is to make the spider housing pendulous, *Fig.* 2.3. Then the spider reaction to the load transmitted will depend on the moment arm of the pendulous weight which will swing out and up until its moment equals the transmitted torque. Thus, the greater the torque the farther the spider arm will swing. It is simple either to calibrate a scale or to calculate one. This method is particularly good since it is not subject to the miscalibration of a spring force and scale can be conveniently changed by merely adding more weight or changing its position. However, it does have the disadvantage of an unavoidable nonlinear scale. On the other hand, this method provides greater measuring sensitivity at the low scale end.

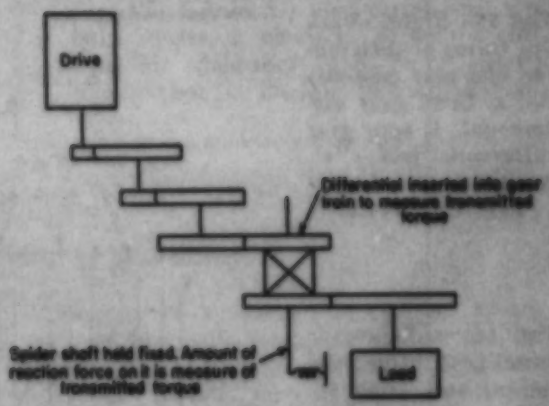

Drive
Differential inserted into gear train to measure transmitted torque
Spider shaft held fixed. Amount of reaction force on it is measure of transmitted torque
Load

Fig. 2.1—Diagram of differential used for measuring torque in a gear train

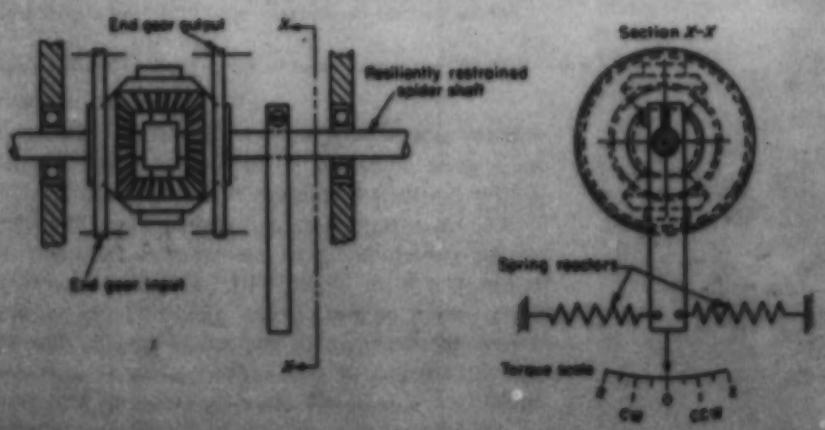


Fig. 2.2 — Differential used as a torque dynamometer by having spider housing react against a calibrated restraint

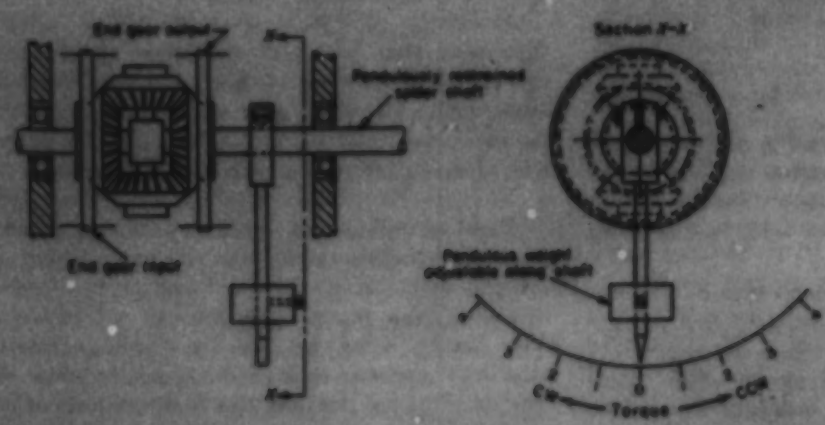


Fig. 2.3 — Differential torque dynamometer using a pendulously restrained spider shaft

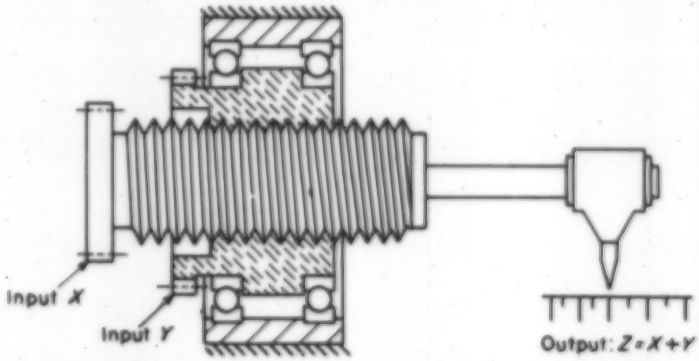


Fig. 14—Simple screw differential

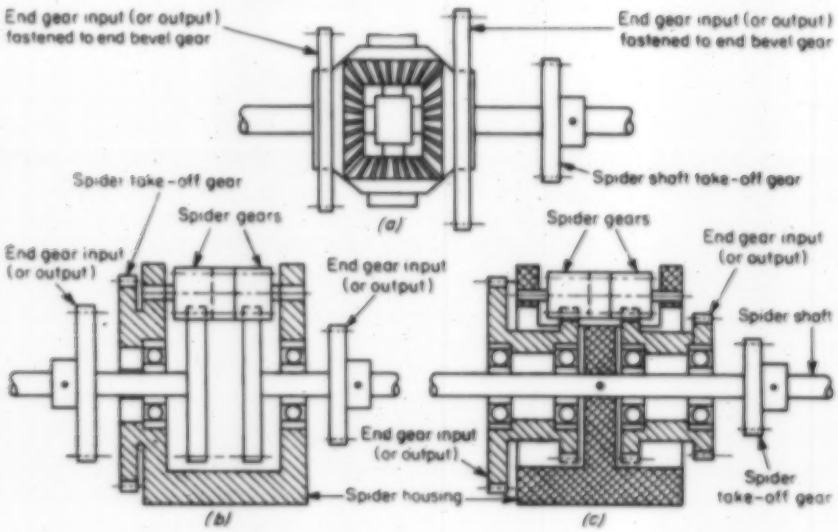
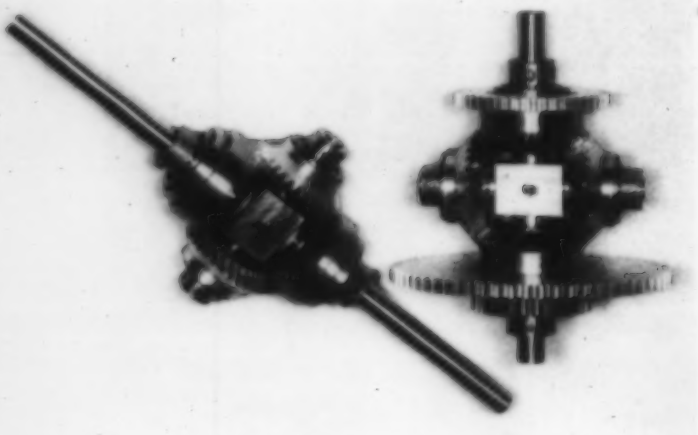


Fig. 15—Right—Various forms of differential end gear take-offs on, *a*, bevel gear differential, *b*, spur gear differential and, *c*, alternate form of spur gear differential

Fig. 16 — Below — Bevel gear differential before and after addition of end gear takeoffs



However, this is not universally followed and therefore the term "input" is often applied to the end gears and similarly "output" to the spider take-off gear, regardless of how they are actually used.

In the case of spur gear differentials, the arrangement of the inputs and outputs will depend upon the design. *Fig.* 15*b*, which is similar to *Fig.* 8, shows a design in which the differential end gears are mounted on independent in-line shafts and their motion is obtainable through spur gears fastened to their respective shafts. The spider gear motion is obtained by means of a spur gear fastened to or made integral with the spider housing assembly.

An alternate design is shown in *Fig.* 15*c* in which the spider gear assembly is fastened to the through spider shaft. The differential end gears have input-output gears fastened to them and rotate in bearings on the spider shaft. The input-output motion of the spider gears is obtained by means of a take-off gear fastened to the through shaft. Thus, this arrangement is very similar to the bevel gear differential.

From the illustrations of *Fig.* 15, it should be apparent that the take-off spider gear and end gears of a differential need not be identical in size. Often the pitch diameters differ, their values being determined by the details of the design of the differential into a specific gear train.

Type of inputs and output will affect incorporation of the differential into the overall packaging of the application. In the case of the gear differential, the inputs and outputs are rotary motion and therefore lend themselves conveniently to gearing. Other forms of differentials offer varied forms of linear motions and combinations of linear and rotary motion. For instance, the rack differential of *Fig.* 11 has linear inputs and output.

as does the linkage differential of *Fig.* 13. On the other hand, the screw differential of *Fig.* 14 is a combination of two rotary motion inputs and a linear output.

Differential symbol is convenient in the preparation of mechanical schematic drawings. The symbol commonly used is a square or circle with a cross as shown in *Figs.* 17*a* and *b*. The cross in the center represents the spider shaft. To further distinguish the spider leg, its portion of the cross is shaded. The other two arrows represent the two end gear inputs. Note there are always two inputs and one output, but the choice is open as to which leg is made the output. The symbolic representation differs from the real units in that the spider axis take-off is oriented normal to the end gear inputs, whereas actually the inputs

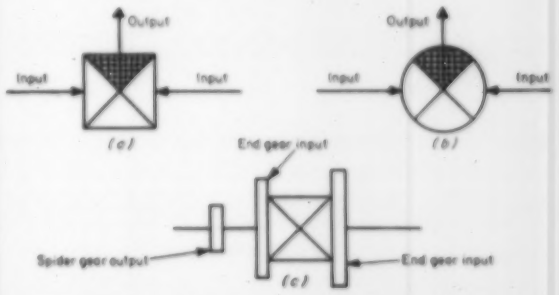


Fig. 17—Commonly used differential symbols: square, *a*, or circle, *b*, with a cross, used in schematics, and more descriptive symbol, *c*, used in gearing diagrams

Application 3—Braking or Clutching

As a brake or bypass, the differential is inserted between the load and drive, but has one leg fixed by means of a clutch, *Fig.* 3.1. The drive will operate the load as long as it is less than the clutch rating of the fixed side of the differential. To bypass the input from driving the load, the clutch-brake is opened and the drive then acts through this open leg of the differential, leaving the load stationary. A further feature is that if the holding power of the brake-clutch is preset, it will act as a safety clutch should the load exceed this value.

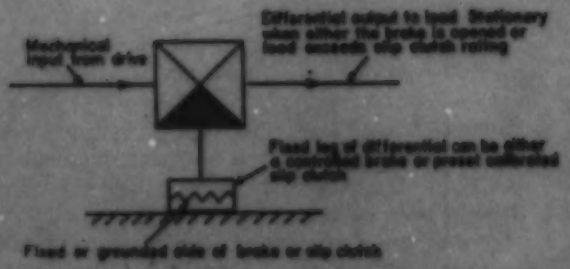

Mechanical input from drive
Differential output to load. Stationary when either the brake is opened or load exceeds slip clutch rating
Fixed leg of differential can be either a conventional brake or preset calibrated slip clutch
Fixed or grounded side of brake or slip clutch

Fig. 3.1—Diagram of differential used as an overload clutch

A more simple means of obtaining an automatic torque limiter is to use the pendulous arrangement shown in *Fig.* 2.3, *Application* 2. Then, if the load unexpectedly rises above a predetermined safe value, the drive torque builds up above the maximum range of the pendulous moment arm and the spider will merely rotate leaving the load stationary. Upon diminishing of the load, the pendulous spider will again reach equilibrium and the load will be driven. Thus, the differential provides a convenient and simple overriding clutch which remains in accurate calibration since it does not rely upon any friction surfaces for holding torque. The design requires correct orientation to action of gravity.

There are limitations to this method of overriding clutch. First, the rotating pendulous spider housing is dynamically unbalanced and therefore is limited to low speed applications. Second, the nature of the pendulous reaction is a peaked curve with a discontinuity. Beyond where the pendulous center of gravity is vertically over center of rotation, reaction is negative in sense, *Fig.* 3.2. Finally, the peaked curve reaction means that such an overriding clutch will not reclutch at any position when the load drops below the rated value, but only that specific position corresponding to where the reaction equals the transmitted load. Moreover, the braking reaction of the pendulous spider is unsuitable in accurate position mechanisms since the spider repositions in accordance with the load. Thus, positional output at load will not be equal to input but will be equal to input minus spider displacement.

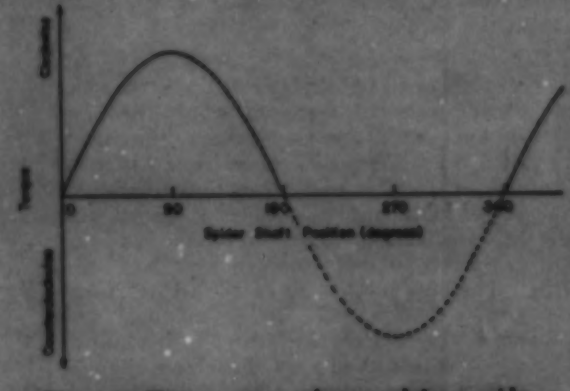


Fig. 3.2—Torque curve of a pendulous spider. Solid portion of curve represents restraining action of spider arm as it rotates away from bottom position. Broken curve indicates negative restraint, or driving ahead reaction, after spider arm is driven over top center and drops down the other side

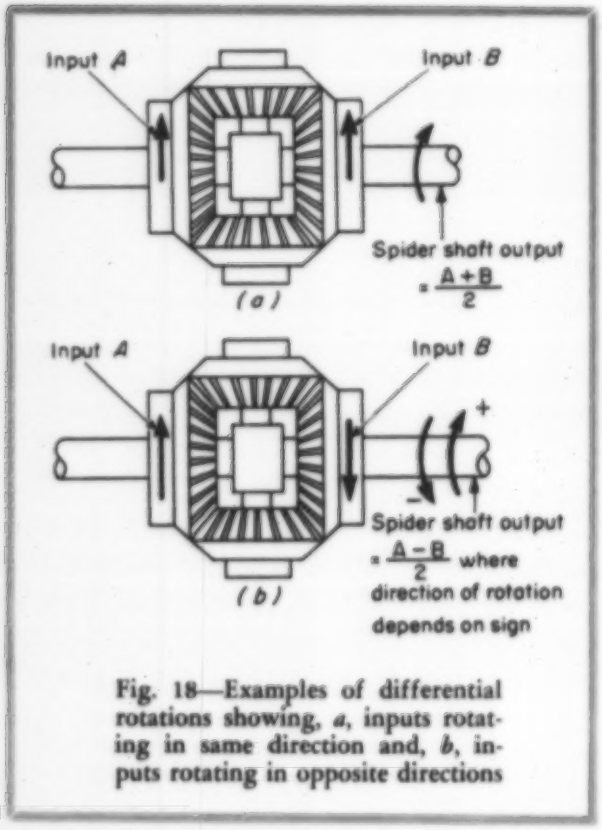


Fig. 18—Examples of differential rotations showing, *a*, inputs rotating in same direction and, *b*, inputs rotating in opposite directions

and output members rotate on coincident axes.

When drawing gearing diagrams, it is convenient to represent the differential with a symbol more descriptive of the unit. *Fig.* 17*c* shows the symbol commonly used, which is similar to the schematic symbol but has end gears added and a central axis representing the spider shaft. In this case, all three gear inputs and output are coaxial, which is true to form, and therefore, it is a more accurate, convenient, and useful way of picturing the differential.

Rules for rotation are helpful for rapid differential analysis.

When both inputs of a differential rotate in the same direction, the differential adds, *Fig.* 18*a*. When the two inputs of a differential rotate in opposite directions, the differential subtracts, *Fig.* 18*b*.

Note that bevel gear differentials are often used for illustrations because they are easiest to picture.

In particular, if inputs are equal and opposite in sense, the quantities being subtracted are equal, giving zero as the answer, with the spider shaft stationary. If the inputs are opposite in sense, but unequal, the spider gears roll on the end gear making the lesser revolutions, and the spider shaft rotates at a rate equal to the difference of input speeds modified by the internal gear factor of one-half.

In the special case when both sides of the differential turn in the same direction for the same number of revolutions, the spider gears do not rotate on the cross shaft. Instead they maintain a fixed position between the end gears and rotate with them, carrying the spider shaft with them.

If both sides of the differential rotate in the same direction, but one end gear makes more revolutions than other, the spider gears will be carried around by both end gears in the same direction and will also roll on the end gear which is rotating at the slower rate.

Applications of mechanical differentials are so numerous and varied that details of each type are beyond the scope of this article. Therefore, only major applications are listed here along with short descriptive comments. There are many other special and general uses of the differential. However, it is hoped the partial coverage of applications constitutes an introduction to their potentialities.

Second part of this series will present a critical analysis of bevel and spur gear designs. Inherent faults and testing will be covered. Finally, practical designs, availability and future possibilities will be discussed.

industrial design Ideas

square eggs

IN a recent magazine article, Harley J. Earl, boss of styling for General Motors said, "Usually, in making gains in appearance, we get better engineering results too."

This is certainly a fact, and it rings just as true when reversed—"Usually, in making gains in engineering, we get better appearance too". This version has special point for machine designers.

Leaf back through your old drawings—you'll find that the simplest, the most straight-forward designs of yours, and the most successful, were invariably the *best-looking,too*. I don't subscribe to the theory of "looks for looks' sake," but I'm convinced that a truly functional product can't help but be better looking, and more successful than one which has been fancied up merely for eye appeal.

For best results, never be satisfied until you've reduced your designs to their lowest common denominator—which reminds me of the old saw to the effect that an egg is the epitome of good design. I've often thought that *square* eggs, like square milk bottles, would be handier for refrigerator storage. (I'll speak to the next hen I see!)

—Cliff

Basic Design Considerations for Electrical Temperature Control

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DESIGN of a temperature-controlled system—whether it be for an oven, a molding press or an elaborate heat exchanger—requires considerably more than simply selecting the heater and a thermostat and installing them in a convenient location. The designer must insure that the system have sufficient heat to meet any reasonable demand, and also that it can be maintained with suitable accuracy at any required temperature level.

Choice of high-quality components does not, of itself, assure good temperature control in a heated system. Control precision is influenced by many other factors. Relative positions of thermostat, heater and temperature-controlled area, degree of heat balance, and thermal characteristics of the materials making up the apparatus, all play a part—and a large part—in determining the accuracy of control obtained.

A very important point is that choice of temperature controller should be geared to realistic requirements of the application. Too frequently, designers have not been as conscious of costs as they could be. In many applications a less expensive controller will not only make possible a lower-cost system, but the control may actually perform better than one costing much more.

This article will discuss some of the major factors affecting the design of a temperature-controlled system and will describe some of the more common types of controller to aid understanding of where each can be best applied.

Basic Definitions: In any discussion of the accuracy of temperature control, three terms will frequently be encountered, *Fig.* 1. These are: (1) controller resolution sensitivity, (2) controller operating differential, and (3) process system bandwidth.

CONTROLLER RESOLUTION SENSITIVITY can be defined as the minimum temperature band required to cycle the electrical contacts of the controller. It is the inherent sensitivity of the controller itself, a measure of the minimum temperature change to which it can respond under the most favorable conditions. This can be thought of as a theoretical

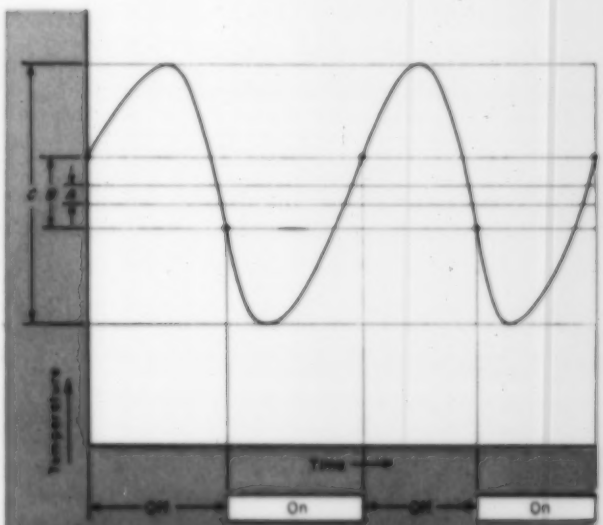


Fig. 1—Basic definitions in temperature control. *A* is controller resolution sensitivity; *B* is controller operating differential; and *C* is process system bandwidth

rather than a practical consideration.

CONTROLLER OPERATING DIFFERENTIAL is the difference in temperature (measured at the outer surface of the temperature-sensitive element) required to cause the contacts of the controller to open and close when the device is in control of a particular process. The distinction is that the operating differential refers to the actual performance of the device in a given temperature-controlled process. The operating differential of a controller will almost always be greater than its inherent sensitivity.

PROCESS SYSTEM BANDWIDTH is the difference between the maximum and minimum temperatures measured at a point in the thermal system which can be considered the useful working area. System bandwidth is an end measure of the practical temperature control effected in a given application. System bandwidth is not merely a function of the operating differential of the thermostat. It is very dependent upon such characteristics of the system as thermal inertia of the heated components, relative location of heaters and controller, variations in heat requirements, heat balance, and frequency of operation of the control element. The mean temperature, the temperature with which the designer is usually most intimately concerned, is a numerical average between the maximum and the minimum bandwidth temperatures.

Selecting a Controller: A wide variety of temperature controllers are available for the designer to choose from, *Fig.* 2. These range from tiny, compact units, particularly desirable where space

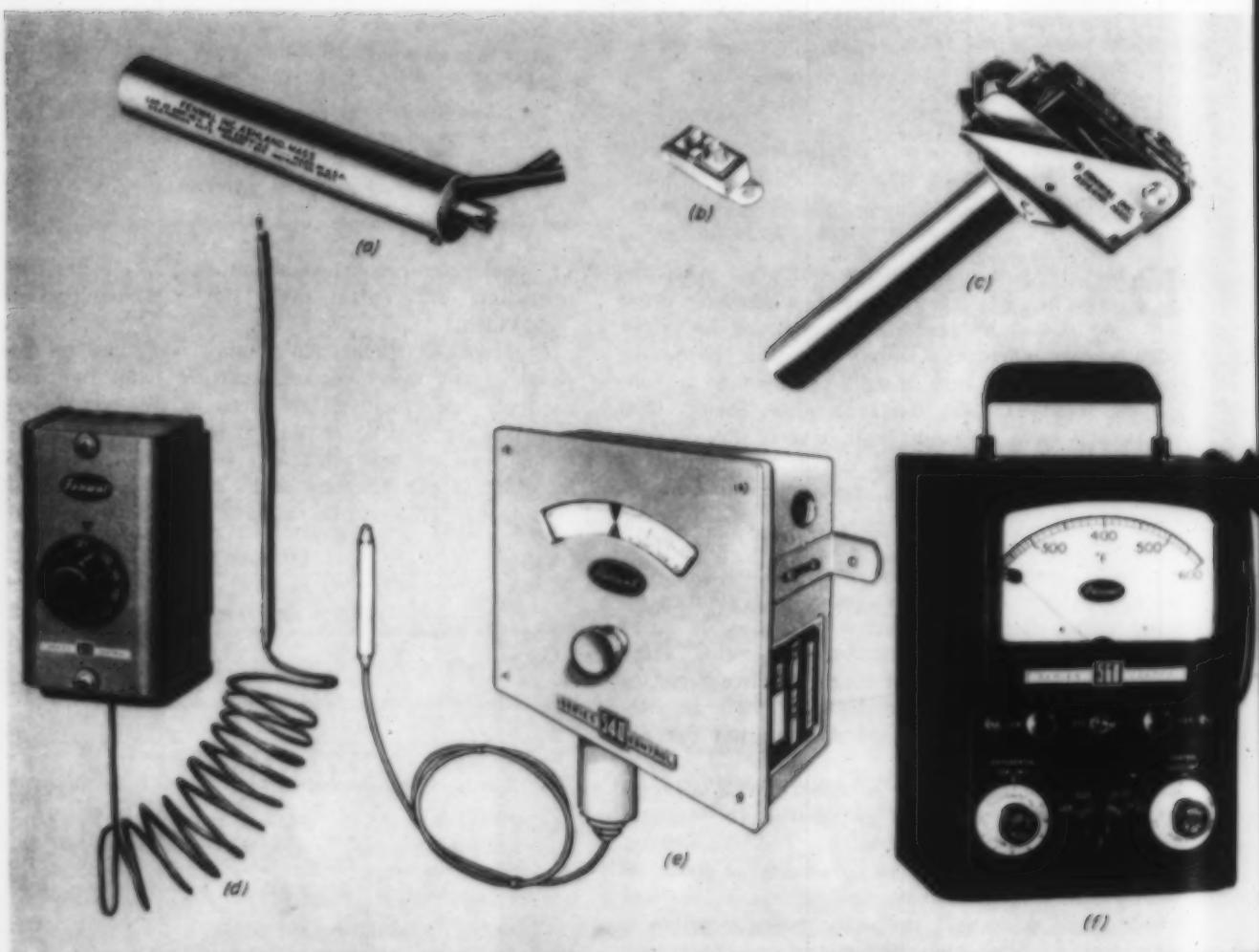


Fig. 2—Typical temperature controllers. Types shown are: *a*, differential-expansion type thermostat for local bulb applications; *b*, miniature differential-expansion type thermostat (approx 1 inch long); *c*, liquid-filled, snap-action thermostat; *d*, liquid-filled and capillary type controller for applications requiring remote setting; *e*, liquid-filled and capillary controller with remote indicator and adjustable differential feature; *f*, thermistor-actuated electronic controller which can be used to provide off-on or proportioning control with adjustable differential

is at a premium and weight must be considered, up to elaborate electronic types which can be located at great distances from the system to be controlled.

In applications where the operator never needs to change the set temperature of the thermostat, or where he can conveniently reach a local type unit if an occasional adjustment is required, one of the less expensive types should usually be selected. If the portion of the controller which responds to changes in temperature must be in an inaccessible location, and the operator must make occasional changes in temperature setting, one of the remotely adjustable types should be chosen.

If a remote type is required, then it should be established whether the operator must also be able to observe the actual temperature of the process at the point where adjustments are made. Remotely adjustable types which also indicate the actual temperature are generally more expensive than the simpler remote unit which contains only a calibrated scale so that the operator can conveniently change process temperature by repositioning a calibrated dial. In general, wherever some other means has already been provided for producing a visible indication of the true temperature of the system, choosing an indicating type controller will result in unnecessary duplication and added expense.

Miniature and midget thermostats, *Fig.* 2, typify the modern trend toward miniaturization which has been largely stimulated by the requirements for airborne equipment. They are by no means limited to that type of application, however. They frequently aid the designer in reducing a cumbersome package to compact size.

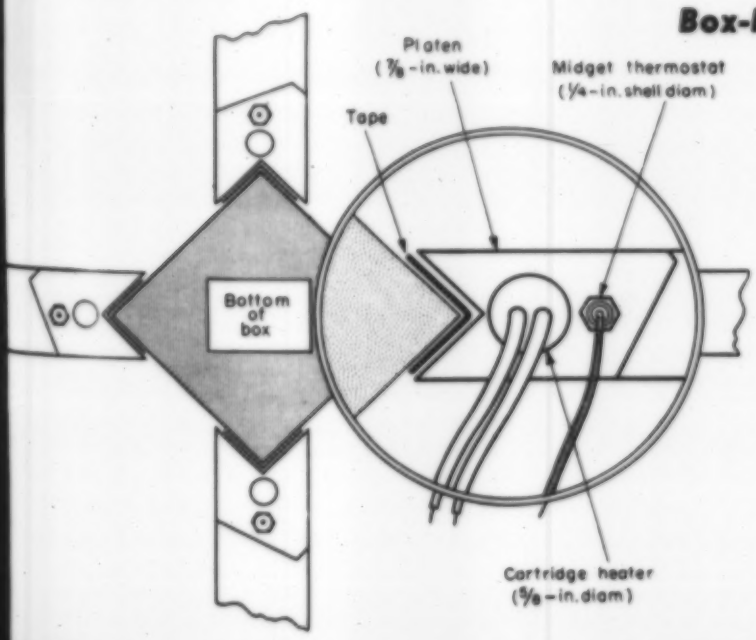
Electric current which can be carried by the various types of thermostat and temperature controllers varies considerably. In general, smaller units are not directly capable of carrying as much current as larger ones. Typical values would be 1 or 2 amperes for miniature and midget sizes, 10 amperes for a cartridge size, and up to 15 amperes for the snap-acting type local thermostat. Units such as the remotely adjustable nonindicating type will operate satisfactorily at currents as high as 35 amperes. Current limitations of smaller types should not restrict their use, however, in applications where they might otherwise be desirable. A relay can usually be incorporated so that the thermostat controls only the relay coil, with the relay in turn controlling higher current which would otherwise exceed the rating of the thermostat.

Before selecting one of the many temperature-control elements, the designer should give careful consideration to the nature of the system controlled.

Selecting the Heat-Exchange Medium: Ideally, the portion of a system housing the temperature controller, the heat source, and the thermal load should be fabricated from materials with high heat conductivity, low density, and low specific heat. Components near the thermal system, but which are used primarily for mechanical support or to complete the package as a unit, should be made of materials which are good thermal insulators, commensurate with mechanical strength requirements.

Good conductivity in the temperature-controlled portion of the system is important to minimize

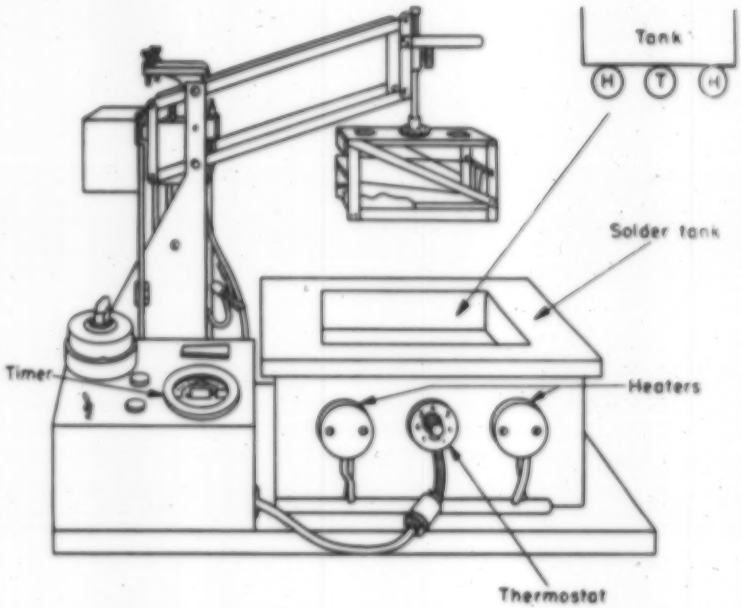
Box-Making Machine



Thermoplastic tape is applied to box corners and fused on by four heated platens with 900 lb pressure. Four different application temperatures are obtained by controlling all heaters with one of the four thermostats. By use of a multiposition switch to select the controlling thermostat, an overall control range of 105 F (35 F difference between thermostats) is possible, with a maximum temperature of 450 F. The highest temperature thermostat also serves as a safety overheat cutoff. A low-energy electronic relay, with thermostats connected to the grid control circuit, provides actual control of the heaters.

Dip-Soldering Machine

Small metal-clad phenolic-plastic panels for printed circuits are coated with solder by dipping. The plastic can withstand immersion for a few seconds in molten solder at 450 F. The thermostat (T) is located at the bottom of the solder tank between the two heaters (H), where it can respond quickly to temperature changes at the heaters for rapid-cycling, narrow-differential control. Exposure period is controlled automatically by an interval timer. An auxiliary three-heat switch for series, separate, or parallel operation of the two heaters decreases initial warm-up time and provides a method of adjusting heat balance for variations in machine operating frequency.



temperature gradients and system inertia, or the time required for the heat wave to travel through the material. Too often overlooked though, are the concepts of light weight and low heat capacity. Weight and thermal capacity of the material directly influence cost of operating the process, since they determine the quantity of heat required to raise the process temperature a given amount.

The term "thermal diffusivity," which is thermal conductivity divided by the product of density and specific heat, is a good measure of the comparative advantages of various materials used as heat-exchange mediums. Diffusivity then is the heat conductivity of a material divided by the heat capacity per unit volume. Not only is this concept important when selecting materials for the heat-exchange medium, but it should also be considered when choosing a primary control element and particularly when choosing some form of well to protect the primary element. *Table* 1 lists relative diffusivity and thermal conductivity of several common materials.

When attempting to evaluate any temperature-controlled system, it must be recognized that, unlike most other measurable quantities temperature cannot be measured instantaneously. An appreciable time is always required for the temperature-sensing element to approach the temperature of the surrounding medium. Even so-called "quick-reading" fever thermometers require a minimum of one full minute before a true reading can be obtained. Response speed of a measuring element will be least important for determining steady-state temperatures. However, it is important when recording temperature fluctuations and rather critical when the element is used to control the temperature.

Use of comparatively slow mercury-in-glass thermometers or bulb-type temperature indicators to evaluate control characteristics of the more sensitive types of primary element used with many temperature controllers can often be very misleading. This is particularly true in rapidly changing systems where the phase relationship between the temperature sensed by the controlling element and that sensed by the indicating element can be displaced by as much as 180 angular degrees, making it appear that the control element is adding heat to the process after it has warmed up and cutting off heat from the process after it has cooled down.

Temperature gradients which might be present in a relatively simple system during a given thermal cycle are illustrated in *Fig.* 3. The three curves are representative of temperatures which could be measured at the heater, at the thermostat, and in that portion of the system which can be considered the useful working area. This set of curves demonstrates clearly that observation of temperature variations at a given point in the system does not provide a true picture of what is happening throughout the system. Temperature will always be highest near the heat source and will decrease at points progressively farther from the heater. Because of this fact, unless the temperature-controlling element is located very close to the useful working area, it may be necessary to adjust it to operate at a somewhat different temperature since it does not sense the same absolute temperature as that measured in the working area.

Even if a material with excellent thermal diffusivity characteristics, such as silver, is used for the heat-exchange medium, a definite period of time

will be required for a temperature change occurring in one part of the system to be transmitted to other parts. This thermal lag results in what is frequently termed "temperature overshoot."

To illustrate by an example, consider the problem of controlling the temperature of a molding press at 300 F. Although the thermostat is set at 300 F, the area immediately adjacent to the heater will reach 300 F and continue to rise before this heat wave has been transmitted to the temperature controller. When the heater is cut off, temperature of the section of the press near the heater may have risen to as high as 310 F. This excess heat will be distributed throughout the system and may cause a subsequent temperature rise at the control element to as high as 310 F. As the system gradually returns to the 300 F temperature and the heater is again turned on, system inertia may result in a measured temperature at the control element as low as 290 F before the heat wave can be transmitted back to the thermostat and reverse the direction of the temperature change.

There are many practical methods for reducing the effect of system inertia if it is objectionable. A control element with a high response speed can minimize the effect. Using a material with relatively high thermal diffusivity, decreasing the distance between the heater and the control element, or installing a small auxiliary heater near the control element may be desirable.

Table 1—Typical Relative Thermal Properties of Materials*

Material	Thermal Diffusivity	Thermal Conductivity
Silver	6.5	242
Copper	4.4	224
Aluminum	3.1	117
Brass	1.2	60
Iron	0.7	39
Stainless steel (416)	0.19	14
Stainless steel (18-8)	0.16	9
Mica	0.009	0.3
Asbestos	0.004	0.1

*Actual values depend upon temperature, exact composition, and previous history of material.

Probably the most important consideration, however, is the realistic degree of temperature control required in the particular application. It is actually possible to obtain temperature control within very narrow limits. However, in many applications, temperature control within very narrow limits is not truly required. Extremely close temperature control should be considered only secondary in importance, since it places an unnecessary cost burden on the apparatus, unless absolutely required.

Actually, initial cost of the temperature control is not always indicative of the precision obtained. Many relatively inexpensive thermostats can exhibit as good or better sensitivity than some elaborate electronic controllers. This is particularly true in units which do not provide snap-action control. By virtue of the fact that contact action is "slow-make," an inherent resolution sensitivity in the order of 0.1 F can be obtained.

Whenever extremely narrow differential temperature control is necessary, and the choice of heat-exchange medium is not fixed because of other factors, it is well to consider the relative advantages of different systems. As a general rule of thumb, which does not take into account individual differences in properties of materials falling within a given class, the order of preference for close temperature control is:

1. Well-agitated liquids
2. Rapidly moving air
3. High-diffusivity metals
4. Low-diffusivity solids
5. Stagnant air
6. Stagnant liquids

Well-circulated fluids can be used to provide closer

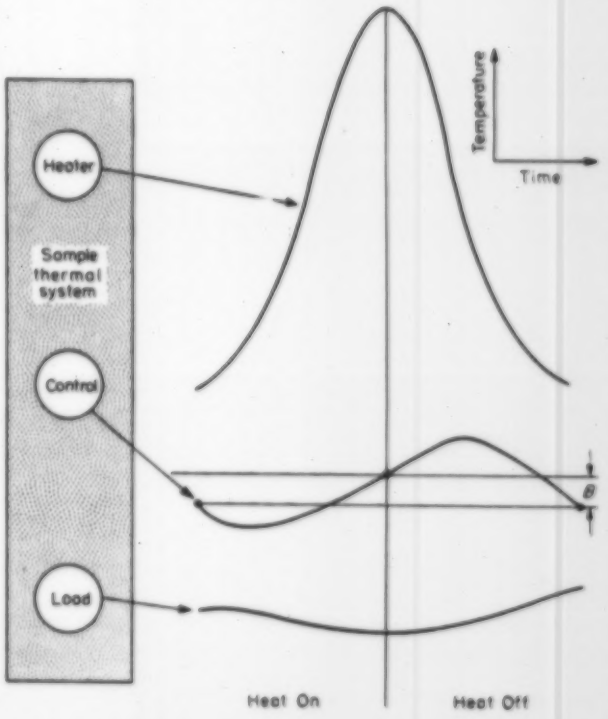


Fig. 3—Temperature gradients in a simple system. Three curves represent temperatures measured at different locations; B is the controller operating differential

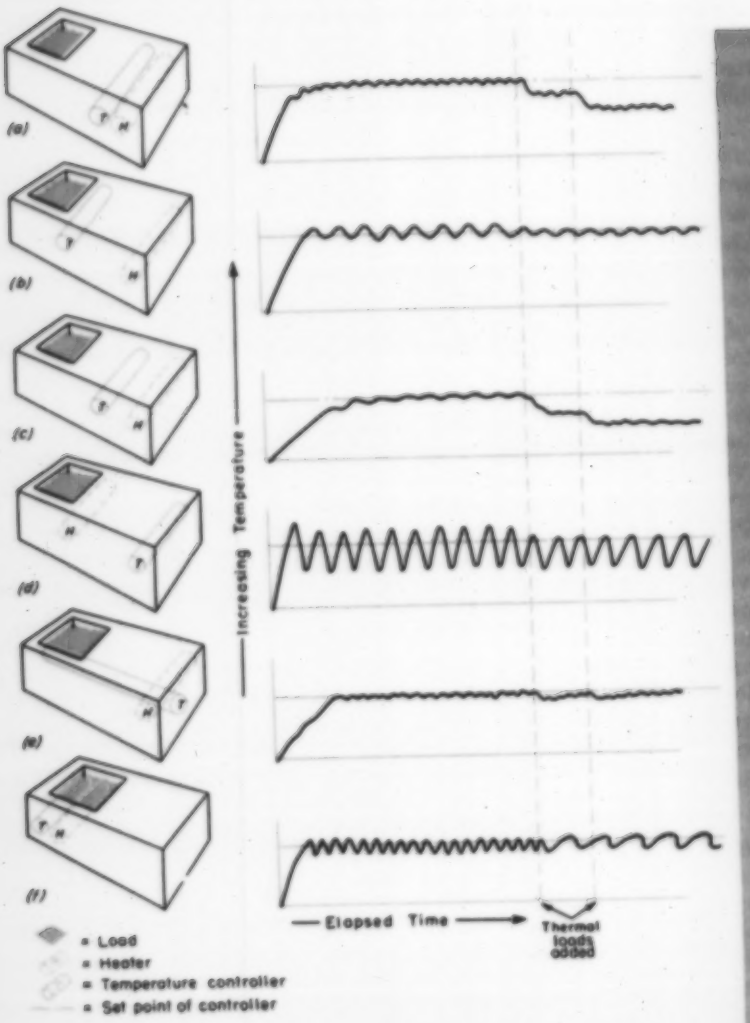


Fig. 4—Effect of Component

Because of the lengthy heat-transfer path between the control element and the load, temperature changes in the vicinity of the load are not detected readily. Accordingly, temperature in the vicinity of the load can vary appreciably outside of the desired limits.

b—Heater distant from load; thermostat at load

In a static system, this arrangement will not provide the very narrow system temperature differential obtained with the arrangement in sketch a. Because of the greater distance between the heater and thermostat, the heat wave cannot be transmitted as rapidly, resulting in greater excursions of controlled temperature, and causing a wider process system bandwidth.

In a dynamic system, placing the thermostat closer to the load has definite advantages in that it can sense changes in heat requirements at the load in a minimum of time. While the system bandwidth may be rather wide due to the time required to sense the action of the heater, the mean temperature at the load will remain relatively constant. Due to the ability of the thermostat to maintain a constant mean load temperature with this orientation, it can be preferable in a dynamic application. Since this arrangement produces a slower thermostat cycling rate, service life of the temperature controller may be increased somewhat, thereby prolonging the useful life of all electrical components.

c—Thermostat between heater and load

This arrangement may be considered as a compromise between the two extremes discussed in a and b. In certain cases, this will be more satisfactory than either of the preceding, since the thermostat is capable of sensing temperature changes either at the heater or at the load rather quickly.

d—Heater at load; thermostat distant

For obvious reasons, this arrangement will result in the poorest control of any that could be selected. It is cited primarily to emphasize the point that relative locations of the heating and controlling components in a thermal system can have a very marked effect on the closeness of control obtained.

With this arrangement, the useful working area is subject to the greatest possible extremes of fluctuation in the controlled temperature, because of its proximity to the heater. With the thermostat remote from both the heater and the load, the maximum possible amount of thermal lag is introduced between the controlling and the controlled elements. Consequently, the load experiences extreme overshoots and undershoots, since the thermostat is not able to monitor the rapidly changing temperature conditions near

a—Heater distant from load; thermostat near heater

In a static system, placing the heater at a considerable distance from the load with the control element adjacent to the heater can result in excellent control in the vicinity of the load. The controller responds very rapidly to temperature changes at the heater, monitoring these changes quickly and accurately, thereby preventing any extreme temperature excursions near the load by eliminating prolonged heating or cooling periods. Provided the heat demand at the load is constant, this arrangement can permit the thermostat to control the useful portion of the system very accurately.

One characteristic of this arrangement is that the controller will cycle quite rapidly. The relatively small amount of thermal lag between the controller and the heater, and the more extreme temperature gradients in the vicinity of the heater, cause the controller to respond more quickly. Service life of electrical contacts actuated by the thermostat can be reduced somewhat due to this rapid cycling.

In a dynamic system where the heat demand of the load may be continually changing, this arrangement would not give optimum control.

Location on Control

the heater. With the thermostat located so far from the heater, system cycling frequency will be reduced appreciably, further jeopardizing accuracy of control.

e—Heater distant from load; thermostat extended between them

For the previous four thermal systems, the general conclusions drawn would apply equally to all types of temperature-sensitive elements. However, when a particular temperature-control element is selected, it is important to recognize what portion of the device responds to changes in temperature. Certain sensors inherently respond to changes in temperature at only a single point. This is particularly true of a thermocouple. Mercury-and-glass thermometers will also approximate this characteristic due to the relatively small size of the temperature-sensitive bulb.

However, many sensing elements can integrate temperatures over a substantially large section of their total volume. Liquid-filled bulbs, *Fig.* 2, are good examples of the latter type. Since control is effected by expansion or contraction of the liquid within the bulb, the actual temperature at which the controller operates can be considered to be an average of the temperature gradient over the length of the temperature-sensitive bulb. Differential-expansion type thermostats, *Fig.* 2, act in much the same manner, since the entire length of the outer shell forms the temperature-sensing element.

Recognition of this ability of certain temperature controllers to respond to an average temperature, rather than a temperature at a fixed point, makes possible an extremely useful application in arrangement *e*. By extending the temperature-sensitive portion of the controller so that part is adjacent to the heater and another part near the load, the unit will respond rapidly to temperature changes either at the heater or at the working area. This can be particularly desirable in providing rapid system warm-up and a reasonably fast cycling rate.

f—Heater, thermostat and load in close proximity

The ideal control will be most nearly achieved if the heater and thermostat are placed in the immediate vicinity of the useful working area. With all components grouped closely together, the heat transfer path is short, so the controller is not handicapped by any appreciable thermal lag. Also, because of smaller mass of the conducting medium, the effects of thermal inertia are minimized. The system cycles rapidly, and rate of recovery from thermal upsets is fast. This arrangement is particularly desirable in installations where the thermal load changes frequently.

temperature control than solids only if forced convection of the fluid is sufficient to overcome the inherent disadvantages in fluids of poor conductivity and slow rate of heat transfer resulting from normal convection.

In addition to fundamental requirements of the heat-exchange medium itself, it is equally important to insulate the heat-transfer material from other sections of the equipment used primarily for mechanical support. In designing a simple barrier between the temperature-controlled sections of the process and those which are used only for mechanical support the concept of thermal conductivity is more important in the support sections than that of thermal diffusivity. A laminated structure consisting of two 1-inch metallic plates separated by a very thin sheet of mica can exhibit 100 times the thermal resistance of a 2-inch metal plate. This practical application of thermodynamics is important particularly in machines where it is necessary to provide metal-to-metal support to obtain adequate strength. Actually, even better than a laminated structure is a thermal barrier consisting of a dead-air space.

Location of Components: Even with identical heaters, temperature controller, and thermal load (head requirements of the material to be controlled, heat requirements of the conducting medium, and heat loss to the prevailing ambient conditions), widely different magnitudes of temperature control can result merely from the relative location of the various components within a system.

Basic location of the various components should be governed by the nature of the application; that is, is it static or dynamic. A static system is one in which the heat demand is practically constant. An example of a static system might be an oven in which a certain quantity of material will be placed for a reasonably long period of time, during which it must be controlled at a given temperature. Such a system will essentially require a constant heat input. A dynamic system is one in which heat requirements vary appreciably. An example of a dynamic system would be a plastic molding press into which cold charges are introduced frequently. These charges must be brought up to curing temperature rapidly, and then held there for short periods of time.

Effects which can be obtained by varying the position of the heater and thermostat with respect to the load are discussed and illustrated in *Fig.* 4, which shows widely differing effects that can be obtained from certain arrangements, including effects of adding thermal loads to the system.

To summarize the possible alternate methods shown in *Fig.* 4, with a *static* system in which heat requirements are comparatively constant, closest temperature control can be obtained by placing the thermostat as close as possible to the heater, with

the load at some greater distance. Ability of the thermostat to respond rapidly to temperature changes around the heat source will introduce a series of rapid pulses of heat into the system, approximating in effect a constant heat input. As long as heat loss of the system remains constant, temperature fluctuations at the load will be kept to a small value.

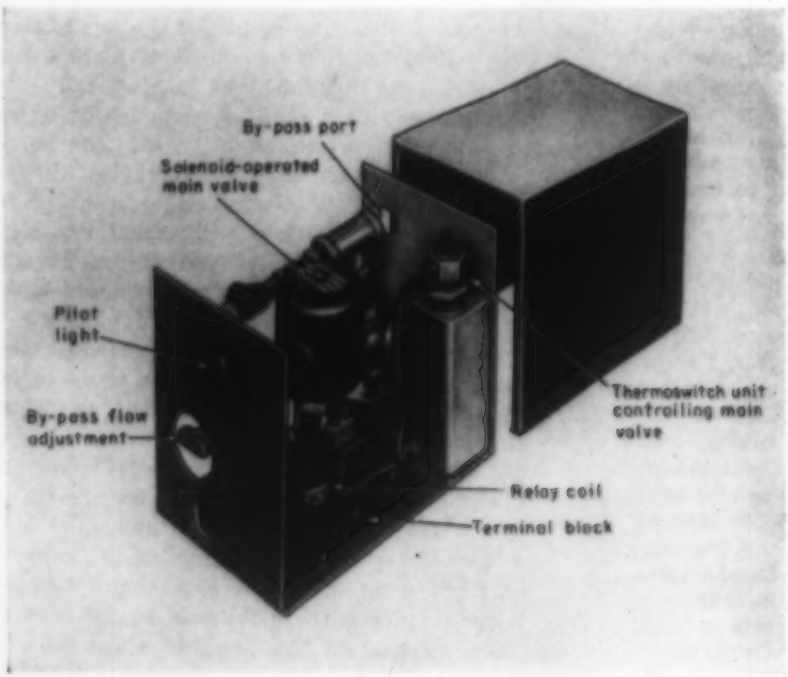
In a *dynamic* system, placing the thermostat near the heater is not generally the best solution. With this orientation, although the thermostat can respond quickly to temperature changes at the heater, it cannot, due to its great distance from the load, respond quickly to changes in heat demand at the useful working area.

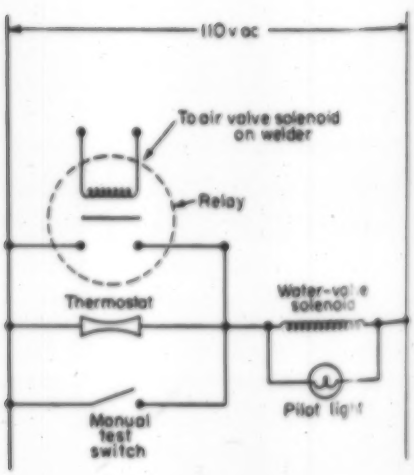
Generally, in most practical systems, the most satisfactory arrangement is to compromise somewhat between the two extremes so that the control element is in a position where it can respond quickly to temperature changes either at the load or at the heater. Closest temperature control will be obtained if the thermostat can be sandwiched between the heater and the useful working area, as shown in *Fig. 4f*.

In a large system, where the effect of thermal lag may be particularly pronounced, it is often possible to obtain a good averaging effect by using a pair of normally closed thermostats wired in series with the heater circuit. One thermostat can be installed adjacent to the heater to act as a high-temperature cutoff to prevent excessive temperature overshoot in the area of the heater. The second thermostat, installed near the load, can respond quickly to variations in temperature in that area. Determining the correct temperature setting for each thermostat will probably be an

Cooling-Water Control

A solenoid-operated water valve with a thermostatic shut-off provides control of cooling water in a unit called the Water Mizer. Used for resistance welders, induction-heating equipment, hydraulic systems, air compressors, etc., the unit turns on cooling water at the initiation of a cycle by means of a relay tied into the operating cycle of the machine. (For instance, it closes when an air solenoid valve on a resistance welder is operated to close the welding horns.) A return water line carries heated-up cooling water back to the thermostat on the Water Mizer. As soon as return-water temperature exceeds the preset thermostat operating temperature, the thermostat closes, completing a parallel circuit to the solenoid valve. When the machine operating cycle ends, the relay is de-energized. But because of the parallel thermostat circuit, the valve is held open until the return water cools down. This feature is not a time delay, but a true thermal delay.





empirical process depending upon heat-gradient characteristics and rate of heat loss from the system, frequency of changes in thermal load, and other factors peculiar to the individual system. Generally, the thermostat near the useful working area would be set at approximately the desired control temperature. The thermostat located near the heater would be set enough higher to provide sufficient heat under conditions of maximum demand and yet prevent the heater temperature from approaching a level which could cause excessive overshoot in temperature near the load.

Although, for simplification, this discussion has dealt with systems having a single source of heat, the same principles apply when the heat source is made up of a large number of scattered small heaters. Temperature gradients will exist, although they will be of smaller magnitude. Locating the thermal element adjacent to any one heater will increase the cycling rate. An ideal solution is to distribute the heating elements throughout the useful working area and locate the thermostat in such a position that it can sense representative temperatures of both the heaters and the section to be controlled.

Effect of Heat Balance and Heater Capacity: Heat balance, a measure of heater capacity with respect to the heat requirements of a given system, will have a direct effect on the temperature control attained. In an evenly balanced system, the heater will be energized 50 per cent of the total time. As a general rule of thumb, if the heater is on more than 60 per cent of the time under normal operating conditions, its rating should be increased; if it is on less than 40 per cent of the time, its rating should be decreased.

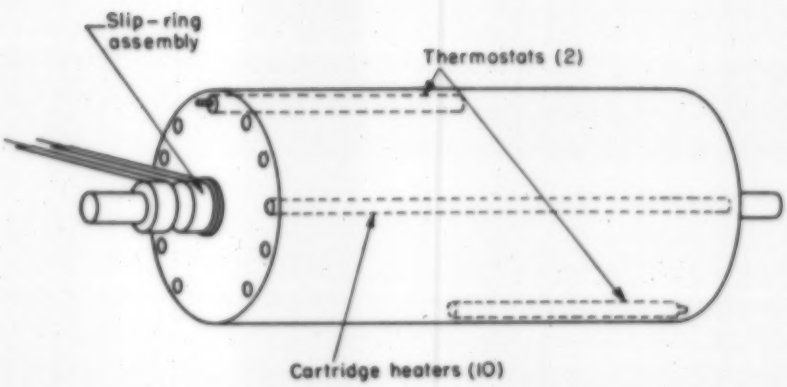
The set of three temperature control curves in *Fig.* 5 demonstrates the importance of correct heat balance in a thermal system. The curve at the left illustrates unsatisfactory control resulting when the heater is several times the required size. In this case, the system temperature rises sharply each time the heater is turned on, subjecting the process to repeated thermal overshoots.

The center curve of *Fig.* 5 demonstrates the control obtained in a balanced thermal system (50 per cent heat-on time). Note that rates of heating and cooling are approximately equal, and that total temperature deviations from the center of the control band are small. The control is good. This system is sufficiently flexible to maintain good control even if the heat demand should increase or be diminished by fairly substantial amounts.

The curve at the right illustrates the control obtained when the size of the heater barely exceeds the basic requirements of the system. Note that even though the heater is on almost continuously, the system is rarely at its controlled temperature. Rate of response to heat demand is extremely slow.

Heated Roll

A heated roll, 3 ft long and 10 inches in diameter, laminates cellophane to paper, or laminates two or three sheets of cellophane. The roll is heated by ten tubular heaters controlled by two extended-leg cartridge thermostats. In this dynamic-heating application, holes for the thermostats and heating elements are bored close to the surface to minimize heat-transfer time. Large mass of the 10-inch diameter cylinder allows it to store up energy during standby periods, which can later be released to the outer surface. Good averaging of temperatures along the length of the drum is obtained by using thermostats which are temperature-sensitive over their total length. Each thermostat controls five heaters—every other one. Anticipation characteristics in the thermostats eliminate any over-temperature surge during initial warm-up.



If for any reason the heat demand should be increased on this already under-rated system, the heater will operate continuously, but the system will never reach the required temperature. This situation, of course, results in complete loss of control.

When heaters are designed into a system, the transfer of heat from the heater to the heat-transfer medium should be as effective as possible. If the transfer medium is metallic, the most efficient heat transfer can usually be obtained by having the heater cast integrally within the block itself. If this procedure is not possible, the heater should be attached securely to the block and be in intimate contact over as large an area as possible. It is particularly essential that all dead-air spaces between the heater and the block be reduced to a minimum; otherwise, large thermal lags will be introduced. Such air gaps can insulate the heater from the rest of the system, causing the heater temperature to be excessive. This can greatly reduce the life of the heating element.

Installations incorporating radiant type heaters can be treated rather differently from those using the more common tubular, cartridge, or strip type elements. Since heat transfer is predominantly by radiation rather than by conduction as with the solid types, it is often possible to minimize the overall thermal mass of the system, thereby substantially reducing process thermal lag. With radiant type heaters, it is very important to make certain that the radiant energy is directed toward the working area by suitable reflectors and that the heaters themselves be placed to insure a uniform distribution of heat.

Regardless of the type of heater selected, it is usually desirable to incorporate the largest practical number of heaters to make up the total desired heat input. The principal advantage of multiple heaters is better, more uniform heat distribution throughout the process, with consequent reduction of extreme thermal gradients among the various portions of the system. The thermal gradient can be further reduced by concentrating more heat where heat losses will be greater, such as near the edges of a molding press, to maintain a more uniform temperature throughout the working area. Another example might be in a long cylindrical body where closer spacing of the heating elements near the ends of the cylinder can compensate for the greater amount of heat dissipated through the end faces. Another distinct advantage of using several separate heating elements in a process is that if it should become necessary to make minor modifications in the thermal characteristics of the systems, individual heaters can be replaced with heaters of a different size to compensate for these changes. Using several individual heaters also minimizes replacement cost in the event that one should burn out.

Proportional Action and Anticipation: In many thermal systems, the controlled temperature must never exceed certain finite limits. An example might be a process in which a material is to be cured, and the curing time can be reduced appreciably by approaching very close to what might otherwise be a destructive temperature limit. Another example would be the control of a liquid system in which the liquid must be maintained very close to its volatilizing temperature. In these cases, where the initial thermal overshoot caused by system inertia during the warm-up cycle would be objectionable, controllers with proportional action or anticipation characteristics can be utilized to good advantage.

The curves in *Fig.* 6 demonstrate the temperature control which can be obtained from simple two-position control action, *a;* average-position control action (sometimes called time-modulated proportional control), *b;* and various degrees of anticipation in the sensing element, *c*, *d*, and *e*.

Thermal inertia will cause some degree of temperature overshoot during the first or warm-up cycle with simple two-position action controllers. Time-modulated proportional control action can be obtained with electronic type temperature con-

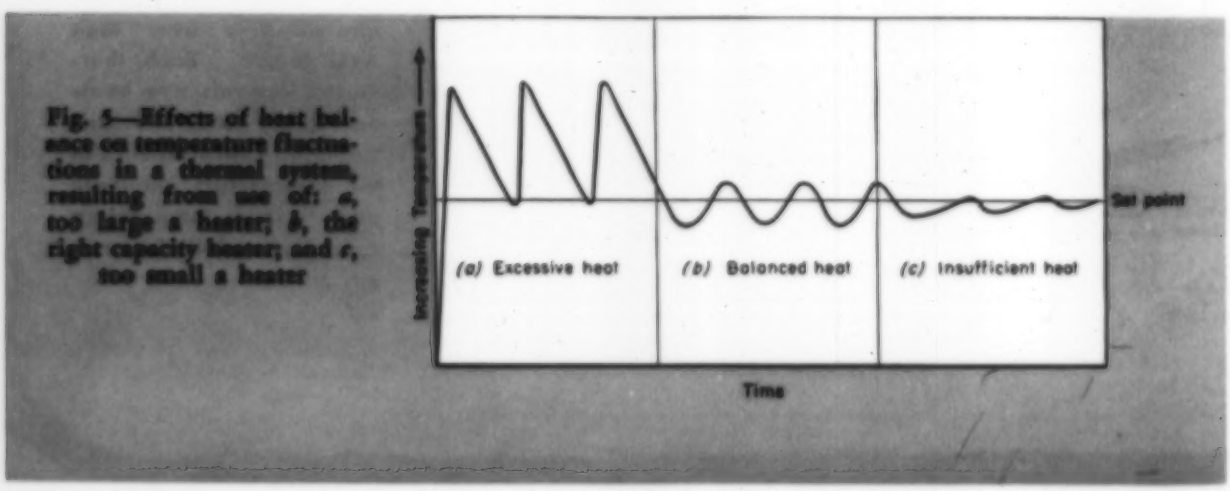


Fig. 5—Effects of heat balance on temperature fluctuations in a thermal system, resulting from use of: *a*, too large a heater; *b*, the right capacity heater; and *c*, too small a heater

trollers, *Fig. 2f*. With these units, a proportional band can be established such that when the system temperature corresponds to the center of the selected band, the heater will be energized approximately 50 per cent of the total time. As the control temperature approaches the extremes of the preset band, the heater on-time will approach 100 per cent at the low end and zero per cent at the high end. This can produce a controlled temperature with an extremely narrow thermal differential. With a properly established proportioning band, the characteristic initial overshoot can be eliminated completely.

Anticipation is peculiar to a class of differential-expansion rod-and-tube thermostats, *Fig. 2a*. Since the outer shell of the unit changes its length in response to temperature changes, varying degrees of anticipation will result from the use of different materials for the relatively low-expansion internal struts on which the contact assembly is mounted.

At higher rates of temperature change, thermal lag causes the temperature of the internal struts to lag appreciably behind the temperature of the shell. This enables the rapidly expanding or contracting outer shell to actuate the contacts sooner than it would at lower rates of temperature change. Accordingly, amount of anticipation will be greater for higher rates of temperature change. The lower curves of *Fig. 6* demonstrate various degrees of anticipation which can be effected with commercially available units, permitting the designer to choose a unit with the optimum amount of anticipation required for his particular thermal system.

Anticipating controllers are particularly valuable when used with thermal systems which are often shut down or which, for other reasons, pass through frequent warm-up cycles, since reheat time can be reduced by using a larger than normal heater without objectionable initial temperature overshoot. Location of the thermostat with respect to the heater affects the degree of anticipation obtained with a given unit to a certain extent. The unit will anticipate more if placed in close proximity to the heater.

In applications where an especially rapid warm-up is important and the characteristic initial thermal overshoot cannot be tolerated, a thermostat with high anticipation can be utilized very effectively in conjunction with several sets of heaters.

The simple relay circuit shown schematically in *Fig. 7a* is only one of many ways of accomplishing this. The relay is actuated initially by an independent warm-up switch or start button and is released when the holding circuit is broken during the first thermostat cycle. Releasing the relay removes the additional heaters from the circuit which had been used to obtain the rapid warm-up. Subsequent control is then effected by the control heaters, which have been sized appropriately to maintain optimum heat balance in the system at

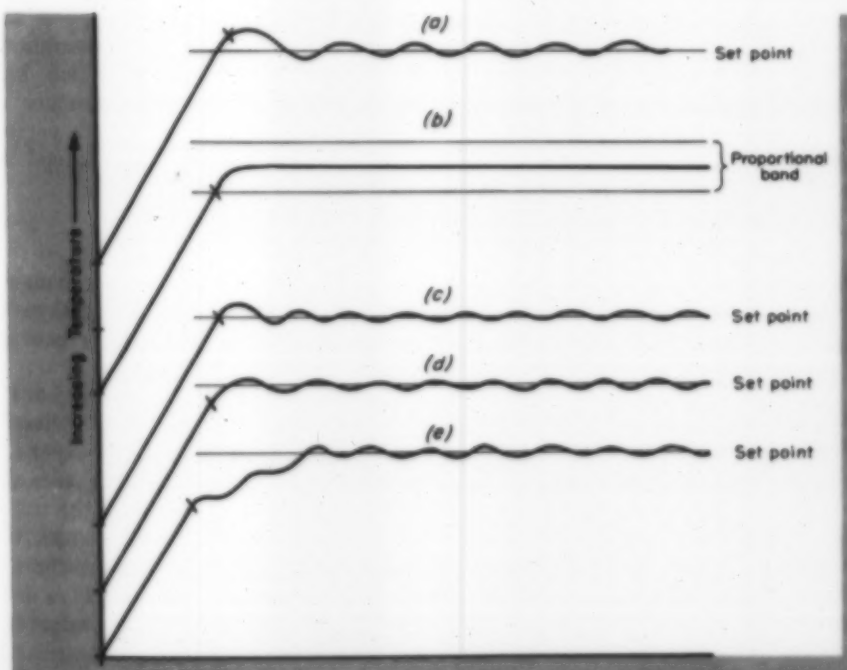


Fig. 6 — Anticipation and overshoot characteristics of various temperature control methods: *a*, simple two-position action control; *b*, average-position action (time-modulated proportional) control; and *c*, *d* and *e*, two-position controllers with little, moderate and considerable anticipation, respectively. Beginning of control action is denoted by *X*.

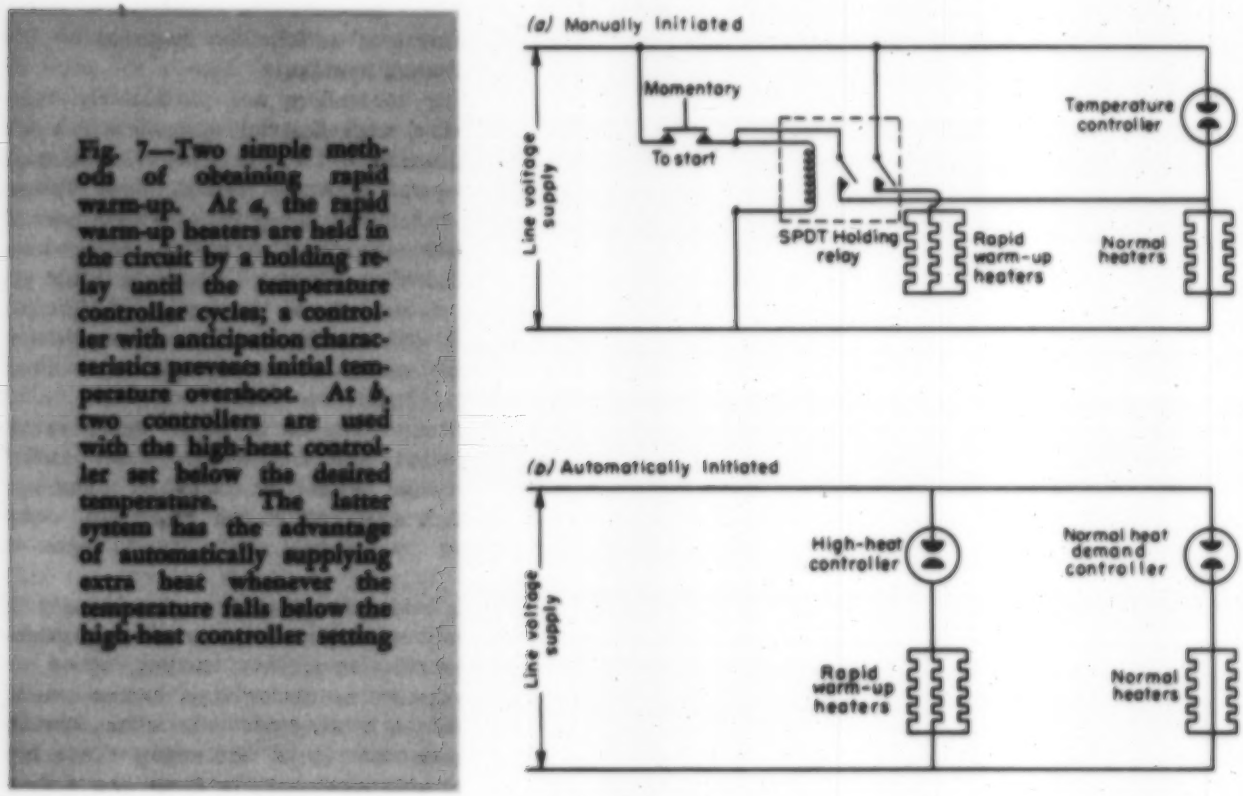


Fig. 7—Two simple methods of obtaining rapid warm-up. At *a*, the rapid warm-up heaters are held in the circuit by a holding relay until the temperature controller cycles; a controller with anticipation characteristics prevents initial temperature overshoot. At *b*, two controllers are used with the high-heat controller set below the desired temperature. The latter system has the advantage of automatically supplying extra heat whenever the temperature falls below the high-heat controller setting

the controlled temperature.

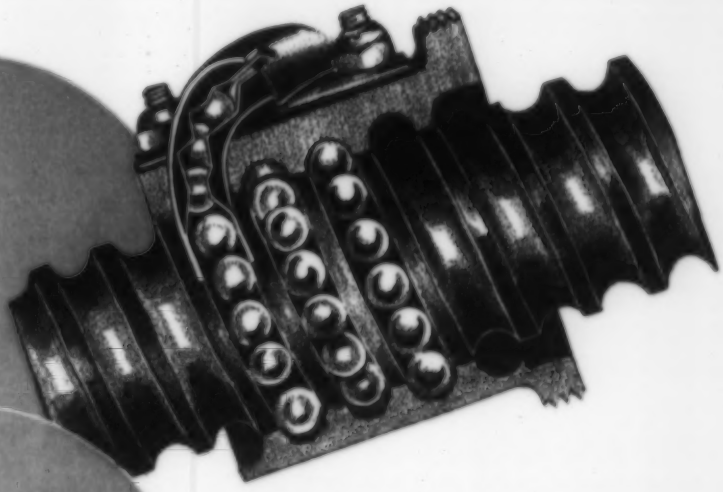
The other relatively inexpensive system, *Fig. 7b*, is based on the use of two thermostats. This combination has the advantage of not requiring any manual action to initiate the high-speed warm-up. One thermostat is set to operate a few degrees below the temperature of the control unit and operates the auxiliary set of warm-up heaters. Temperature setting of this thermostat can be established so that the warm-up heaters will not cause an objectionable initial overshoot. Proper temperature setting for the second or auxiliary thermostat, in order to provide the maximum heating rate without objectionable overshoot, can usually best be determined experimentally. This arrangement is quite flexible, particularly because placement of components to provide optimum control after the system stabilizes need not be influenced by the need to prevent overshoot during the initial warm-up period. It also has the advantage that the rapid warm-up feature is provided automatically even during a short period of shut-down, or if a new batch of material is added to the process.

"We commonly think of business as a joint venture of capital, management and labor.

"Today this concept is a rather dangerous oversimplification, because it fails to recognize the fact that a larger and larger proportion of our people in industry fall into a *fourth* group which both plans its own work and then does it. These are the highly trained people in the professions—the engineers, the lawyers, the accountants, the doctors—of which the engineers are, of course, the largest element in point of number by far."—DONALD L. MILLHAM, *vice president, General Electric Co.*

"Scientific and engineering research in the United States is the living fountain from which comes the wealth of products, comforts and conveniences that has made us the envy of other nations. The riches that have poured out from American research have come from skyrocketing investment in laboratories, experimentation and research workers of all grades.

"According to Dr. Raymond H. Ewell, Assistant Director for Program Analysis, National Science Foundation, in the 1920's all operating expenditures for research in the United States totaled about $200 million per year. In the 1940's the total rose to $400 million a year. In 1953 it reached $3,760 million and in the current year it will approximate $4 billion. This is exclusive of capital outlays and includes only operating expenditures by industry, federal and state government agencies, universities and colleges, applied research institutions, commercial research laboratories, private foundations and trade associations."—J. D. A. MORROW, *president, Joy Mfg. Co.*



Design Guide

BALL-BEARING SCREWS

Basic Types
Operating Principles
Construction Details
Application Considerations
Selection Factors

By David A. Galonska
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ONE OF THE most efficient methods of power transmission, the ball-bearing screw is based on the fundamental physical principle that there is less friction in rolling than in sliding contact. Mating thread surfaces are not in direct engagement but are separated by rolling balls. As a result, friction losses are low and operating efficiencies will run over 90 per cent, which is substantially higher than can be achieved with other comparable devices.

In a typical ball-bearing screw assembly, *Fig.* 1, the screw and nut each have mating helical ball races. Within the nut, the length of this race is filled with steel balls. A tubular ball guide on the nut interrupts the path of the balls, deflects them from the helical race and guides them diagonally across the outside of the nut and back into the helical race. This construction thus forms a closed circuit through which the rolling balls, as the medium of force transfer, recirculate con-

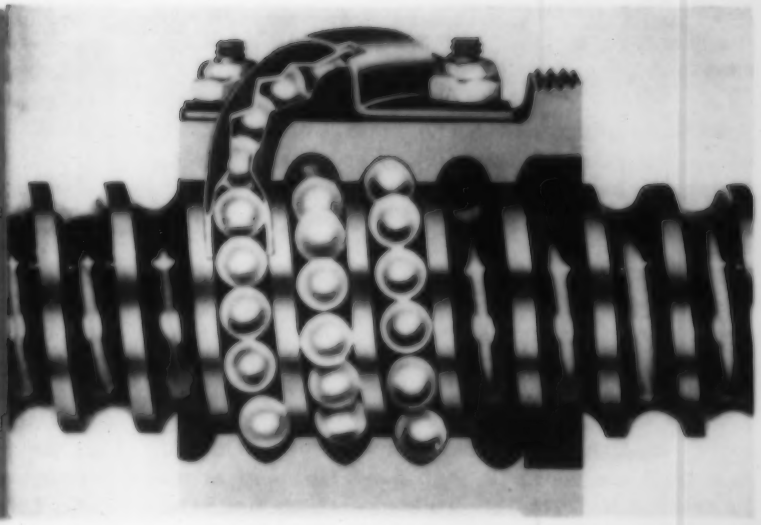


Fig. 1—Typical ball-bearing screw assembly employing threaded nut with single ball circuit. Projecting guide finger on return tube deflects balls into tube for recirculation

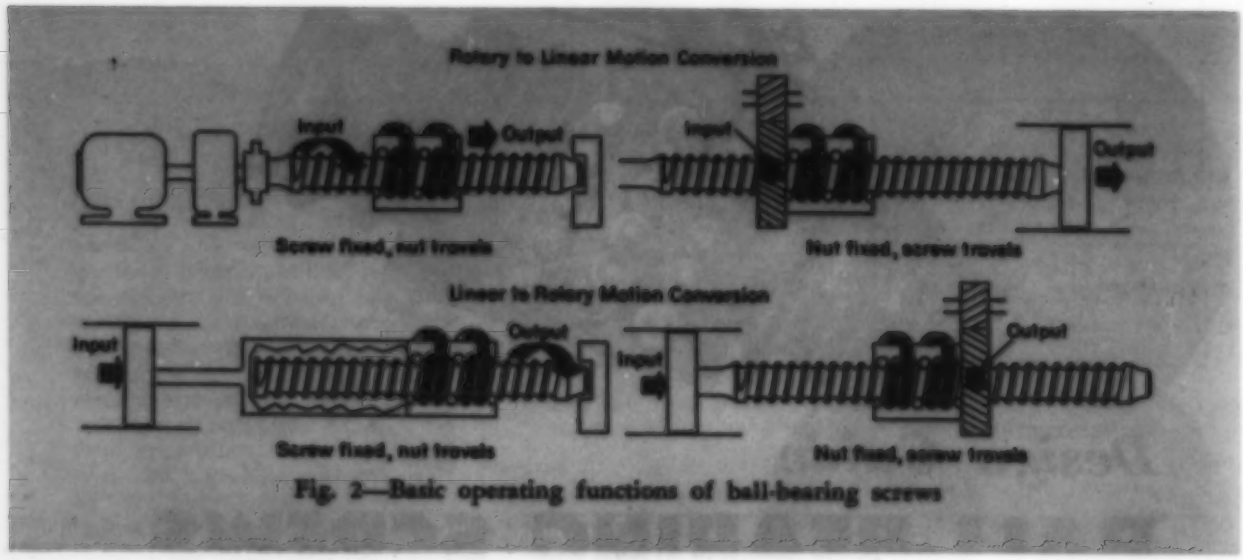


Fig. 2—Basic operating functions of ball-bearing screws

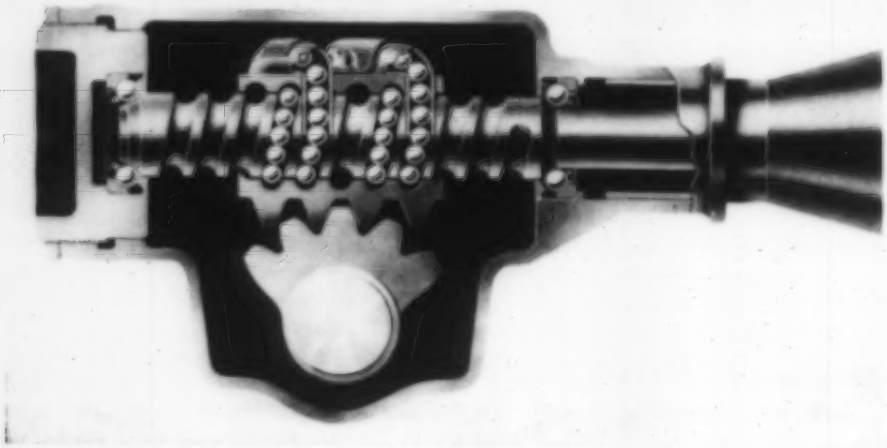


Fig. 3—Automotive steering mechanism in which the conventional worm drive gear is replaced by a ball-bearing screw assembly. Manual operation of the steering wheel is transmitted to the pitman sector gear through rack teeth on the ball nut. Backlash of the nut is controlled by varying the pressure of engagement, or side load, to produce different deflections of the screw

tinually as the screw and nut are rotated relative to each other.

In practice, this basic design may take a number of forms. Many different types and sizes of screw assemblies have been developed, offering a wide range of performance characteristics to match varying application requirements. In the discussion to follow, the important basic types of commercial ball-bearing screw units and the factors influencing their selection and application will be considered.

Basic Considerations: The conventional function of the ball-bearing screw is to convert rotary to linear motion. The nut generally serves as the output member and is driven along the longitudinal axis of the screw as the screw rotates. This method of application is the most common and offers the highest efficiencies, however, other equally useful operating arrangements are also possible.

An important feature of the ball-bearing screw is the so-called "reversibility" characteristic which permits adaptation of the device for linear-to-rotary motion conversion. Two arrangements of this type are shown in *Fig.* 2, which summarizes in schematic form the basic operating functions of ball-bearing screws. Efficiencies under reverse-action conditions are not as high as for the other systems but will as a rule run over 80 per cent.

Potential applications of the ball-bearing screw include a wide range of mechanical functions either as a power-transmission unit or as a linear or angular positioning device. The first major application of the principle was in an automotive steering mechanism developed by Saginaw Steering Gear engineers. A recent model of this design is shown in *Fig.* 3. Rack teeth on the bottom side of the ball nut, which has a rectangular cross-sectional shape, mesh with corresponding teeth on a sector gear mounted to the pitman shaft. The steering shaft is connected directly to the screw. Manual operation of the steering wheel at the end of the shaft rotates the screw which, in turn, drives the nut back and forth through a double ball circuit arrangement to actuate the sector gear and, thus, the steering linkage.

Except for certain housing and bearing modifications, the model shown in *Fig.* 3 is substantially the same as the original. Extensive operating experience with the design in both heavy and light-duty automotive applications over a number of

years has proved the ball-bearing screw mechanism to be both rugged and efficient under continuous as well as intermittent operating conditions of service.

Screw Design and Construction: Although all commercial ball-bearing screws are basically similar, certain details of design and construction will vary with different manufacturers. Moreover, these units have not been generally standardized and methods of load rating and specification may also differ among manufacturers. For understanding, it will perhaps be worthwhile to review some of the more important aspects of commercial design practice.

Table 1—Standard Rolled-Thread Ball-Bearing Screw Assemblies*

Ball Circle Diameter (in.)	Ball Diameter (in.)	Thread Lead (in.)
0.375	0.0625	0.125
0.631	0.125	0.200
1.000	0.15625	0.250
1.171	0.28125	0.41304
1.500	0.34375	0.47368
2.250	0.375	0.500
3.000	0.500	0.660

*Lengths limited only by material stock sizes.

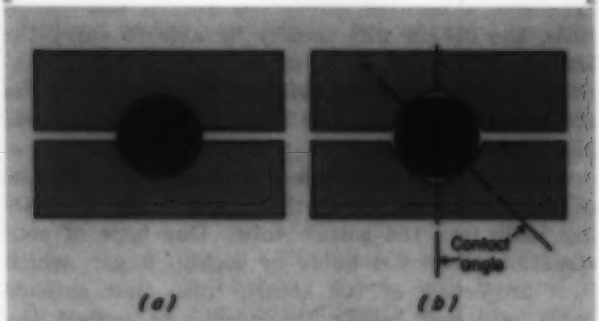


Fig. 4—Above—Basic grove designs for ball-bearing screws showing, *a*, circular arc construction and, *b*, gothic arch modification

Fig. 5—Below—Heavy-duty ball-bearing screw assembly which has three ball circuits and yoke type ball deflectors

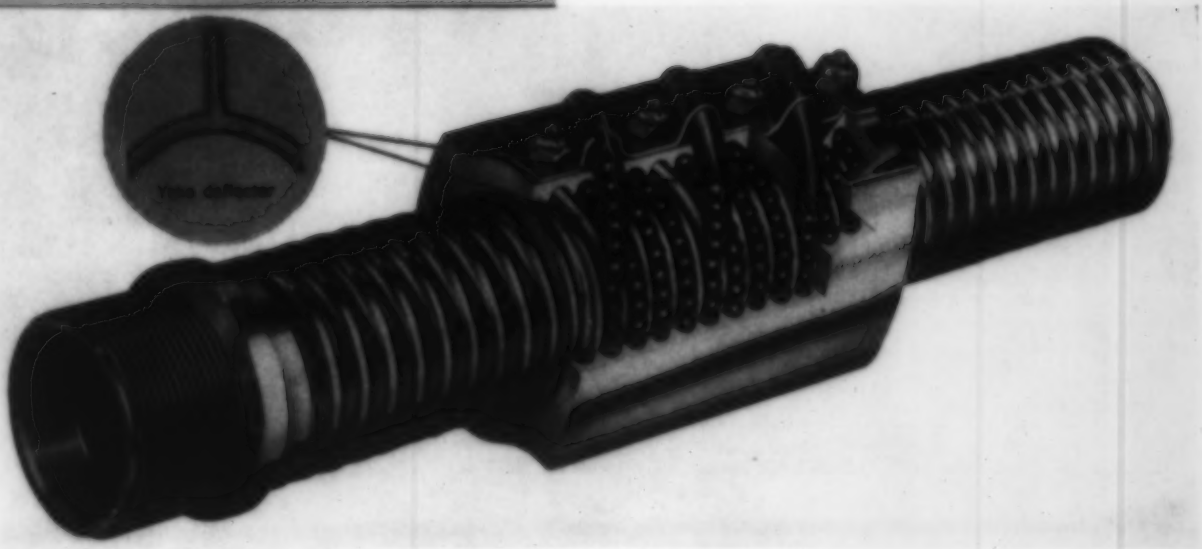
Two terms are useful when dealing with ball-bearing screws: *lead* and *ball circle diameter*. As in the case of conventional threads, lead is defined as the distance the nut advances for one revolution of the screw. For ball-bearing screws, lead is usually specified as a decimal dimension but may also be given in terms of threads per inch, depending on the conventional practice of the particular manufacturer.

Ball circle diameter or, as it is sometimes called, pitch diameter is a convenient measure of nominal screw size and is based on the circle of ball centers. It is defined as the diameter of a circle whose radius is the distance from the screw axis to the center of one of the active bearing balls. This dimension is always slightly larger than the OD of the screw thread.

Screw threads are generally produced by two methods: machine grinding and rolling. Rolled threads are suitable for most general-purpose applications where life, load and operating conditions are within the normal range. For severe operating conditions, however, where long life at high loads is important, or when heat treatment is necessary to achieve certain material properties, machine-ground threads are preferred.

In the past, commercial ball-bearing screw assemblies have usually been custom designed to fit the particular application. However, with the introduction of rolled threads, certain standard sizes have been developed and are now available, *Table* 1. Where they can be used, rolled thread designs may offer appreciable cost advantages. At the same time, the quality of machine ground units may often be justified by the nature of the application requirements.

Two thread groove designs have been developed



for ball-bearing screws, *Fig.* 4. The circular arc design, *Fig.* 4*a*, is analogous to that used on the races of conventional ball bearings. The "gothic arch" design, *Fig.* 4*b*, is a modification developed to provide control of loading conditions. With the gothic arch construction, foreign matter that enters the active ball grooves can be pushed aside by the balls into the space provided by the diverging arcs.

The contact angle of the ball is measured from the vertical center line of the groove; the smaller the angle, the higher the stress imposed on the ball. Design of the gothic-arch groove shape is usually based on a 45-degree contact angle for a better control of lash. In the circular groove, contact angle varies with change in load and lash.

Ball nuts are essentially of two types: single and multiple circuit. The construction in *Fig.* 1, for example, is of the single-circuit type. To increase the load capacity of a ball-bearing screw, it is necessary to increase either the ball diameter, screw diameter or number of bearing balls. The first two options, however, are not always possible because of lead or space requirements.

One way of increasing the number of balls is to increase the number of turns in the single-circuit design. However, this method may produce a tendency toward jamming, so alternate smaller diameter spacer balls or "drones" are often also added to provide the necessary freedom of motion. Another way to increase the number of balls is to provide more circuits, *Fig.* 5. In the multiple-circuit construction the separate circuits divide the load equally and every ball is a load carrier, eliminating the need for the extra nonworking spacer balls.

Both types are equally efficient, although as loads increase the single-circuit design usually results in a longer and heavier nut because of the extra spacer balls. In addition, the multiple-circuit type has a built-in safety feature: if one circuit fails, the others will usually be able to carry the load until repairs can be made. The significance of these various features will, of course, depend on the nature of the specific application and cost considerations.

Another aspect of ball nut design that can be of importance is the method used to direct bearing balls into the return tube. One type of construction utilizes a guide or pickup finger, which is a projection of the return tube, that extends down into and blocks the groove to deflect the balls into the tube for recirculation. A more rugged construction that offers greater reliability under severe operating conditions, although at a

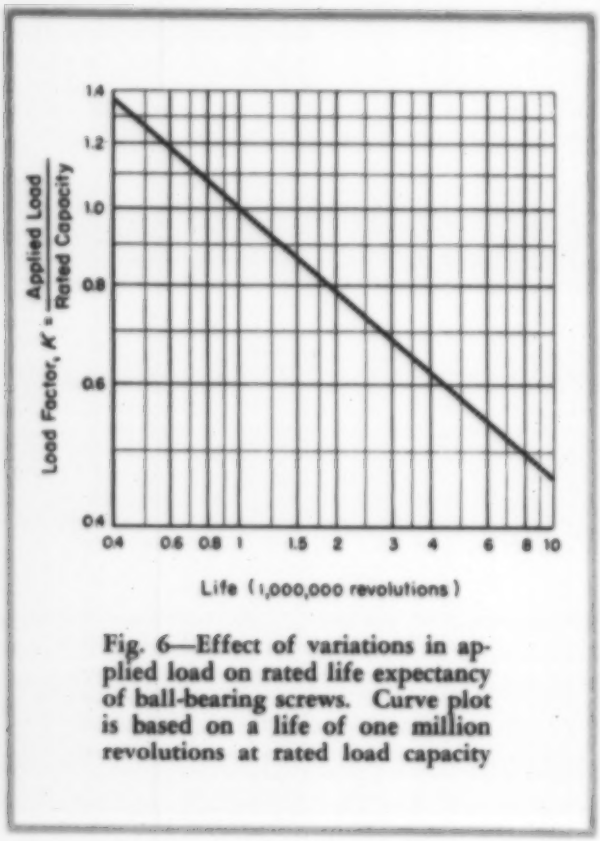


Fig. 6—Effect of variations in applied load on rated life expectancy of ball-bearing screws. Curve plot is based on a life of one million revolutions at rated load capacity

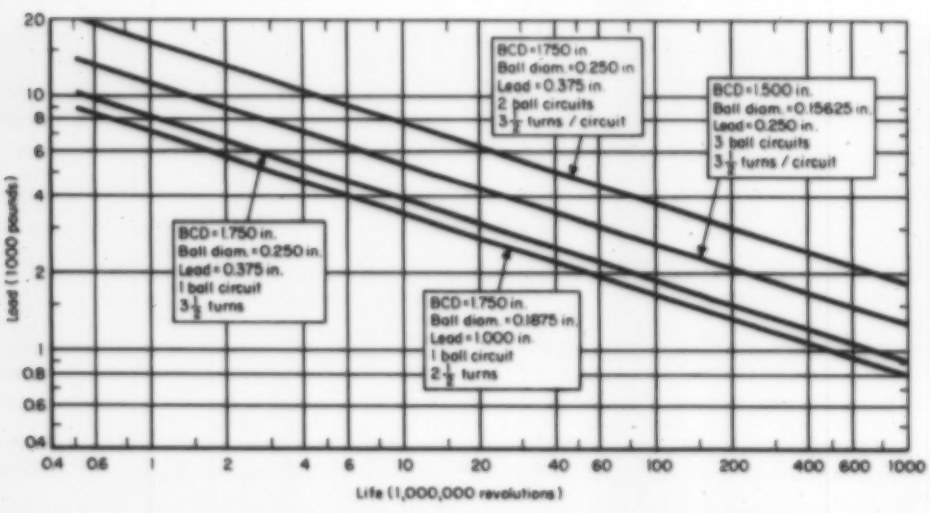


Fig. 7—Life-load characteristics of four similar ball-bearing screw designs. Curve data are based on concentric loading and material of Rockwell C-60 hardness

higher cost, employs separate yoke deflectors, *Fig.* 5. The yoke, a patented Saginaw development, presents a larger, hardened solid surface to deflect the ball and acts as a scraper to keep the active grooves free of foreign matter.

Ball-bearing screw assemblies have been successfully produced in a wide variety of screw, nut and ball combinations. Range of screw sizes produced varies approximately from 1½ inches to 39 feet in length with ball-circle diameters from ¼ to 18 inches. Screw length is usually limited only by available material bar-stock sizes while the range of diameters is a function of production facilities. All screws below ½-inch ball circle diameter are supplied with solid center; however, the larger sizes can be obtained with center bores.

A screw lead of 0.125 or ⅛-inch is usually recommended as the practical minimum, although values of 0.10-inch have been achieved. Ball size will, of course, have an influence on the minimum lead for any particular screw design. Above the minimum value, however, there is virtually no restriction and almost any lead up to infinity (the theoretical value of lead in a spline) is possible. An exception is in rolled-thread designs where groove sizes and leads are limited by production techniques.

Further design possibilities are offered through the use of different materials. Chrome steel is the standard ball material, and the nut and screw are usually heat-treated alloy steel. Stainless steels are also commonly employed. Additionally, a number of special ferrous and nonferrous alloys and heat treatments have been used to meet severe or unusual operating requirements. Stellite balls, for example, have been effective as a means of providing high wear resistance. Where noise is a problem, molded nylon balls can be employed in combination with a steel screw and nut. In this

Table 2—Representative Design Data for Ball-Bearing Screw Assemblies

Ball Circle Diameter (in.)	Ball Diameter (in.)	Thread Lead (in.)	Maximum Screw Bore (in.)	Operating Load* (lb)	Maximum Static Load† (lb)
0.500	7/64	0.1406	0.25	630	3325
0.500	1/8	0.500	0.25	1225	5250
0.625	9/64	0.1428	0.32	735	4200
0.750	5/32	0.1875	0.38	1310	7000
0.875	1/8	0.200	0.50	1770	9450
0.980	9/64	0.16304	0.56	1250	7700
1.000	5/32	0.166	0.62	1260	14,700
1.000	7/32	0.222	0.62	2800	10,850
1.000	9/32	0.250	0.62	2800	14,700
1.150	1/4	0.200	0.70	2110	12,600
1.200	1/4	0.375	0.62	6300	30,450
1.250	5/32	0.2857	0.75	3230	18,200
1.500	7/32	0.250	0.88	3670	22,050
1.625	7/32	0.3636	1.17	5000	29,050
1.710	1/4	0.2656	1.18	5180	30,800
2.500	3/8	0.500	1.75	17,640	98,000

*Based on 3½ active turns of balls and a life of one million revolutions. †Based on 3½ active turns of balls.

Fig. 8—Two models of line of Harnischfeger welding positioners in which ball-bearing screws may be used to control table motion and position. Number and length of screw assemblies varies according to model capacity, but all are of same basic rolled-thread design: 3 in. BCD, 0.660-in. lead, ½-in. ball diameter. In 20-ton model at left, table operation is controlled by two screws; in 10-ton model at right, only one screw is used. Telescoping covers protect the screw threads against weld spatter

case, however, quiet operation is achieved at the expense of a reduction in load capacity. Other unusual problems that have been solved through special material combinations include submerged operation in liquid oxygen, nitric acid and liquid metals. In addition to materials variations, design options are offered on a number of different standard protective coatings and finishes.

Selection and Application Factors: For simplicity of design analysis, it will perhaps be helpful to think of the ball-bearing screw as a combination of three fundamental mechanical units: (1) a power transmitting shaft, (2) a ball-bearing and (3) a screw thread. Features of each of these units are found in the ball-bearing screw assembly and often a direct analogy of construction and operating characteristics is possible and will be a useful aid in analysis.

Load Capacity: Static and operating load capacities for a representative group of ball-bearing screw assemblies are given in *Table* 2. Load values are based on 3½ active turns of balls and a life of one million revolutions.

Load characteristics of a ball-bearing screw parallel those of a conventional ball bearing. Each screw assembly is designed to carry a specific load for a specific number of cycles. This operating load is a function of the number of active load-carrying balls in the screw assembly and the fatigue properties of the ball material.

Load ratings are determined by laboratory testing under simulated service conditions and are usually specified in terms of one million revolutions or, in some cases, one million inches of nut travel, with the load acting in one direction. Where the actual load differs from rated capacity, the life expectancy of the screw assembly in hours will vary approximately as the cube of the ratio of the rated capacity to the applied load, where rated capacity is dependent on ball travel only. A graphical interpretation of this general relationship, based on a life expectancy of one million revolutions at rated load, is shown in *Fig.* 6. In this plot, it will be noted that the load factor, *K*, is actually the ratio of the applied load to the rated capacity.

Life-load curves for four similar ball-bearing screw designs are shown in *Fig.* 7. All of the units were developed for the same application. A comparison of these curves is particularly interesting from the standpoint of the effect of the different construction variations on life expectancy and load capacity.

Although the applied load may in practice differ from the rated capacity, it should never exceed the recommended maximum static load. This latter value is based on the load at which brinelling of the screw will occur and is directly proportional to the number of active load-carrying balls. Most manufacturers incorporate a margin of safety in the recommended value as added protection against possible failure.

As mentioned previously, rated capacity and/or life expectancy of a ball-bearing screw design can be varied by changing either the ball diameter, the screw diameter or the number of bearing balls, *Fig.* 7. Another method of achieving different load capacities, which has certain advantages, is the use of varying numbers of screw assemblies of the same size. An example of the application of this technique is furnished by a line of welding positioners, *Fig.* 8, in which ball-bearing screws can be used for control of linear table motion and position. The same basic rolled-thread screw design can be employed on all of the models in the line and different load and operating requirements met by varying the number of screw assemblies used and the screw length. As a result of this approach, cost of the ball-bearing screw units has been reduced and standardized assembly has simplified design and production problems.

Column Loading: Since a ball-bearing screw takes the form of an end-supported beam when mounted, it is subject to the effect of column action when loaded in compression. This effect may or may not be of importance, depending on the specific application, but should be checked to assure that the screw diameter-to-length relationship is adequate. Typical column load curves for a number of different screw sizes are given in *Fig.* 9. These curves are based on Euler's formula for pin-ended columns and represent the calculated values for hollow screws with maximum bore diameters. If column loads exceed the curve values for a particular screw size, the next larger ball-circle diameter should be considered.

Within their defined limits, these curves are useful as an approximate guide to screw selection but should not be taken as a measure of true column load capacity. Where loads are on the borderline, or end-support arrangements deviate from the defined conditions, final screw dimensions should be checked with the manufacturer's recommendations.

Power Requirements: Linear speed of the ball nut may be readily determined from the screw rotational speed and lead of the screw thread. Output power can then be calculated from the value of maximum load and, if the efficiency of the screw assembly is known, the input power can be established.

Efficiency of a ball-bearing screw assembly will vary for different screw designs and operating conditions. However, where the operating function is one of rotary-to-linear motion conversion, which is the usual case, efficiencies will generally range from 90 to 98 per cent. The efficiency curve shown in *Fig.* 10 is typical and illustrates the effect of helix angle, or lead, variations. For horsepower calculations, an efficiency value of 90 per cent is reasonable for rolled-thread designs, 93 per cent for machine-ground screws.

Lead, or thread helix angle, will depend on the specific application requirements but is influenced

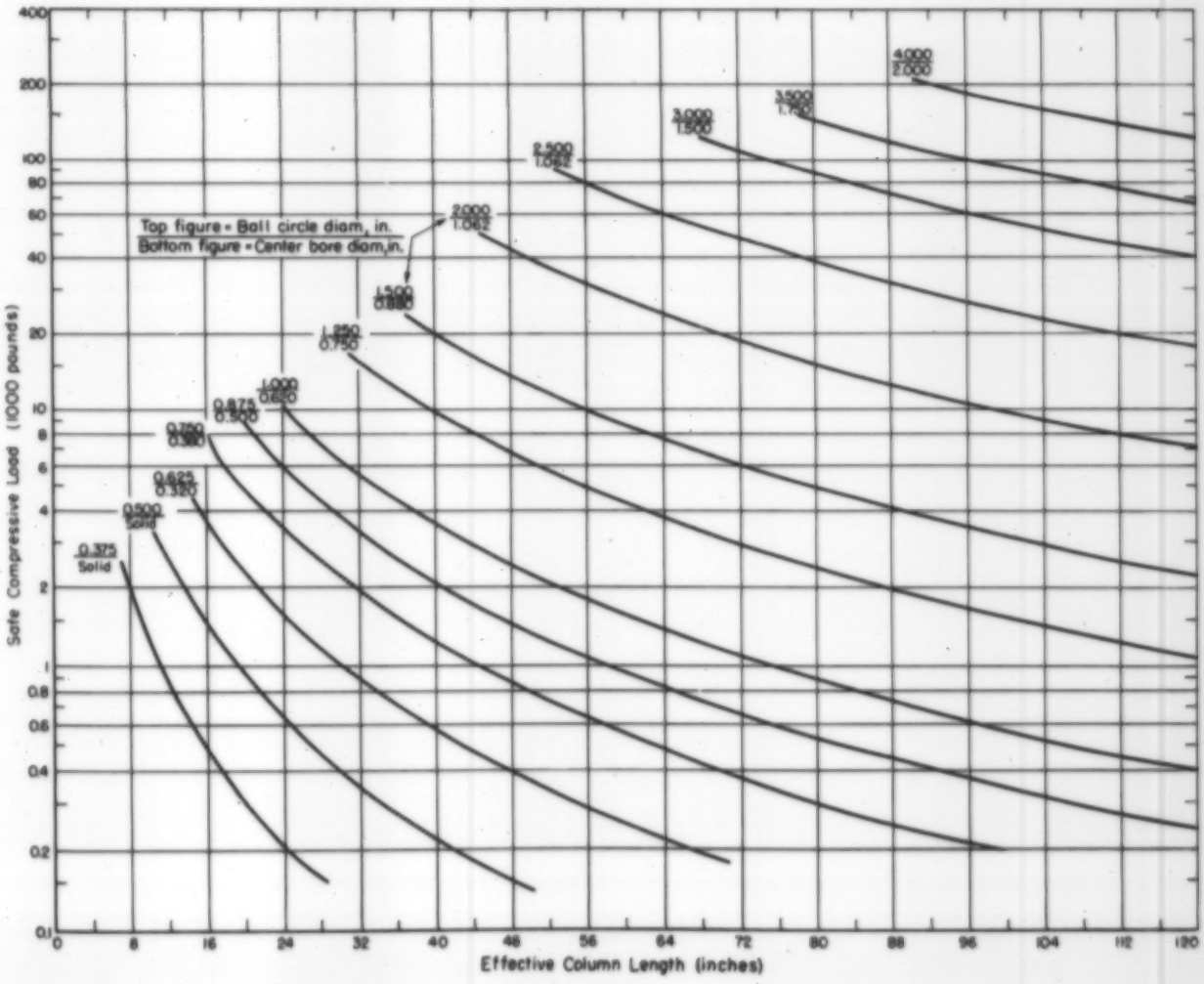
by several considerations, including the distance to be traversed, speed of travel, and precision of control required for position adjustments. As lead is increased, life expectancy of the screw assembly in terms of nut travel will be lengthened; however, the input torque requirement will be greater. As shown by the curve in *Fig.* 10, the effect of lead variations on efficiency is relatively minor when the helix angle is greater than 2 degrees.

Screw Mountings: A basic consideration in the application of a ball-bearing screw assembly is the method of screw mounting. In general, the recommendations of conventional design practice for power transmission shafts will apply and should be followed. Antifriction bearings are always preferred for end mounting; otherwise, the high efficiency of the ball-bearing screw assembly may be partially lost in overcoming bearing friction. In the selection of antifriction bearings, however, care should be exercised to assure that bearing capacity corresponds to that of the screw assembly.

Possible methods of power connection are as varied as for transmission shafting and include the usual standard techniques such as gears, splines, clutches, keys and flanges as well as others. When flanges are employed, diameters should be kept to a minimum to avoid excessive machining costs. On rolled thread screws, particularly, bearing diameters should not exceed that of the screw stock. From the standpoint of economy, threaded or press-fit flanges mounted against positive shoulder projections are preferred.

An important point to consider in screw selec-

Fig. 9—Safe column loads for representative ball-bearing screw assemblies. Curve plots are based on Euler's formula for pin-ended columns



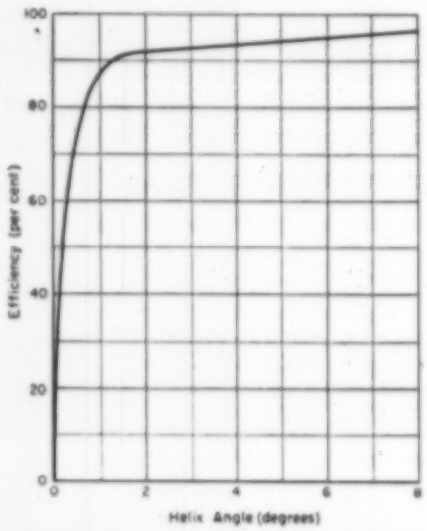


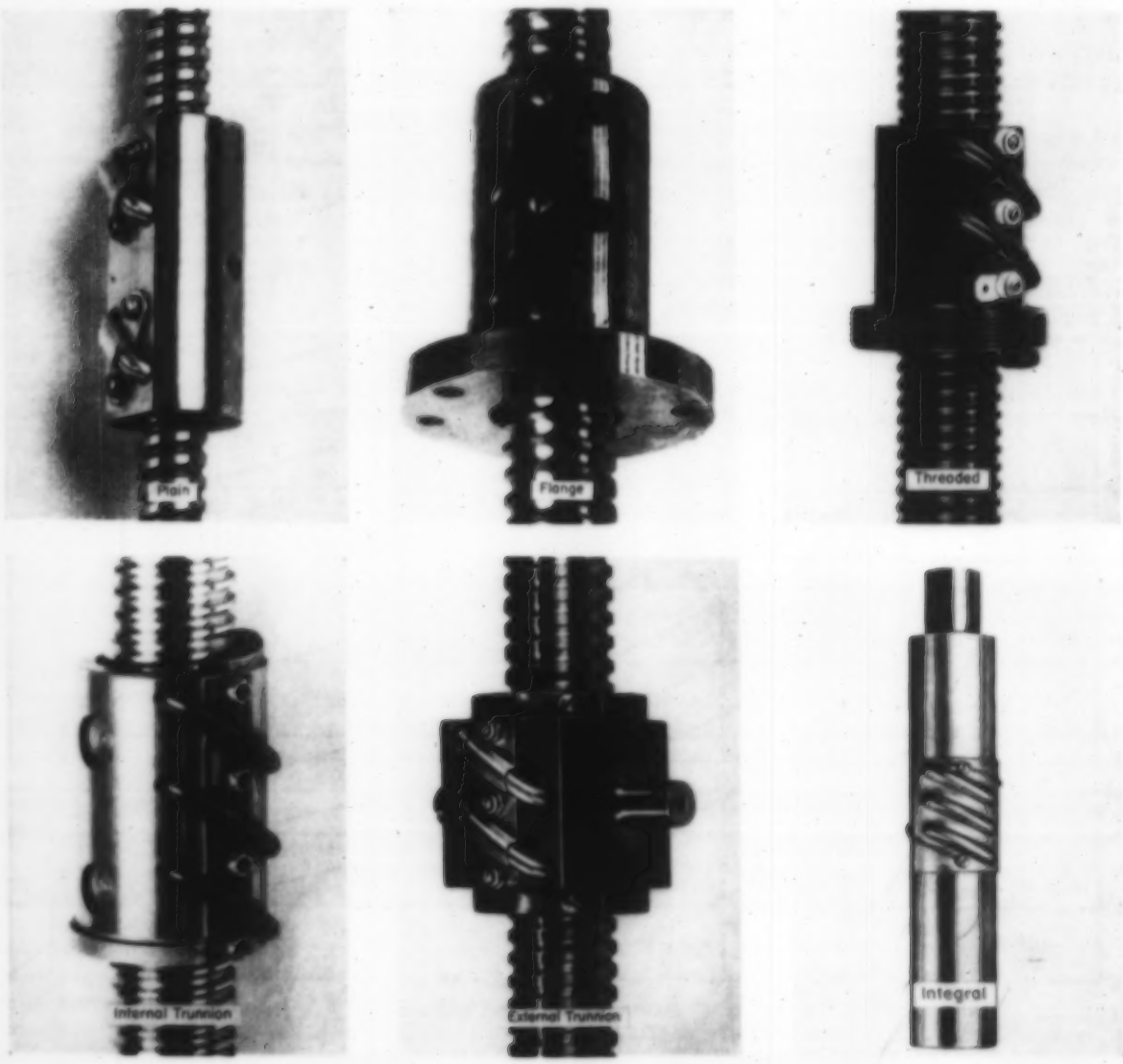
Fig. 10—Effect of thread helix angle on ball-bearing screw efficiency

tion and mounting is the condition of critical speed. This condition, which occurs at a specific operating speed in end-mounted shafts, is almost identical to the natural vibration frequency of a comparable stationary shaft and can produce a whirling action of destructive amplitude. Recommended design practice for ball-bearing screws is to keep operating speeds at least 20 per cent above or below the critical value.

For a given screw installation, critical speed is a function of bearing location and the effective length, diameter and material of the screw. A change in any of these variables will alter the critical speed value. Equations for calculating critical speed values can be found in several places in the literature,* or ball-bearing screw manufacturers may be consulted for operating speed recommendations.

*Kents Mechanical Engineers Handbook—Design and Production Volume, Twelfth Edition, edited by Colin Carmichael, John Wiley and Sons Inc., New York, 1950, Section 9-13.

Fig. 11—Basic types of nuts for ball-bearing screws



Critical speed conditions are avoided by selecting screw and mounting dimensions which will hold the operating speed well below the critical value. Unlike a turbine shaft, for example, where the rotational speed of the shaft is brought above its critical frequency and continuously operated in a safe range between harmonics, a ball bearing screw has to be brought up to speed and stopped two times for every operating cycle. Passing through the critical range in this manner would produce destructive effects on the assembly.

One of the most effective and practical methods of varying critical speed conditions in ball-bearing screws is the use of different mounting arrangements. When single end bearings are employed, the result is essentially a nonrigid mounting which gives about the lowest critical speed value. Double end bearings, on the other hand, provide a more rigid mounting which permits operation at much higher speeds. Speeds up to 9000 rpm, falling safely below the critical range, have been achieved with such arrangements in practice. For a rigid mounting, it can be shown that the critical speed value is approximately 2¼ times greater than that for a comparable nonrigid screw mounting arrangement.

Another useful method of avoiding critical speed conditions is to increase the lead of the thread, thus permitting the screw to be operated at a lower speed for a given rate of linear nut travel. Where space requirements permit, of course, there is always the option of selecting a screw of larger diameter to provide the added stiffness necessary for safe operation.

Nut Design and Mounting: Six basic types of nuts have been developed for use with ball-bearing screws, *Fig.* 11. Construction of ball circuits and other details will vary with different manufacturers but, in general, these nut designs are representative of present practice.

Ideally, loads should be applied uniformly at the ends or sides of a nut so that the resultant force is along the longitudial axis of the assembly. Loads

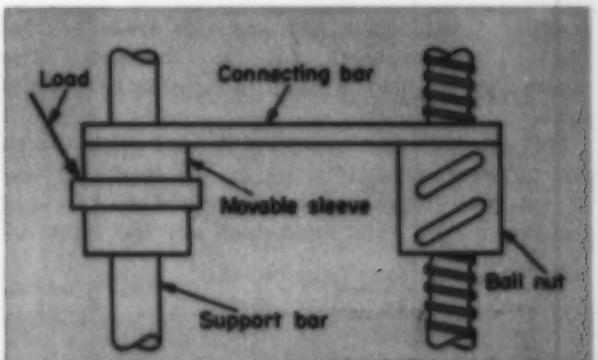
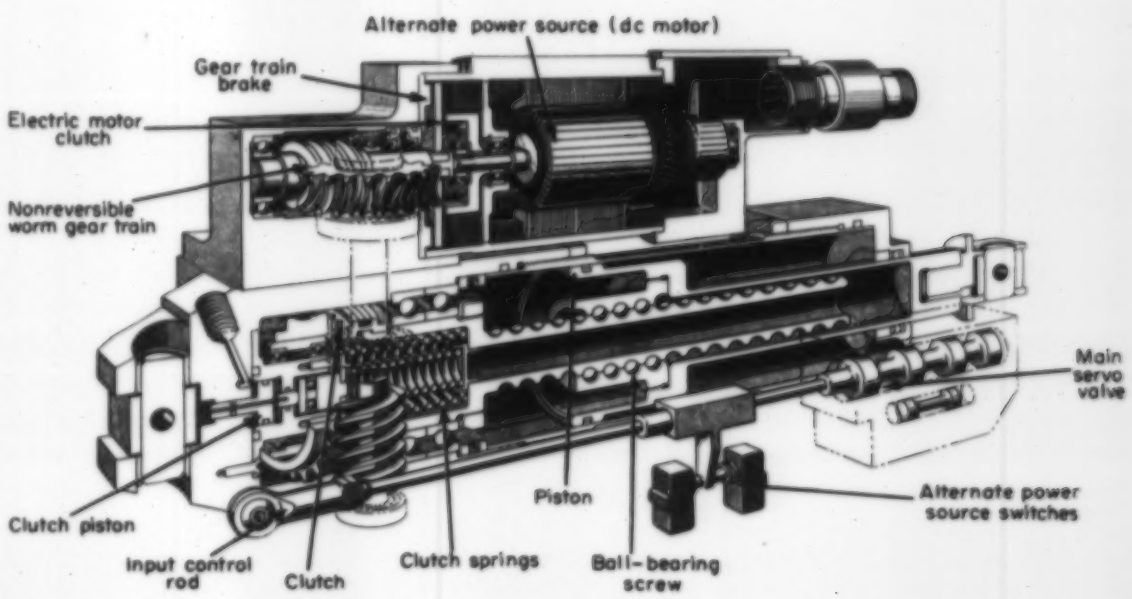


Fig. 12—Method of mounting ball-bearing screws by means of secondary bar supports. Side loads are absorbed by the sleeve, assuring uniform axial loading at the ball nut

Fig. 13—Self-locking hydraulic actuator in which a ball-bearing screw is mounted directly to the piston by means of a threaded nut. Screw assembly serves as a mechanical locking device to provide accurate control of piston position and also permits emergency electrical operation of the actuator if the aircraft hydraulic system should fail. The unit is employed on jet and other aircraft applications and is manufactured by Aeroproducts Operations, Allison Div., General Motors Corp.



which tend to produce a cocking action of the nut create dangerous force conditions and should always be avoided. Also, for thin-wall nuts with long trunions, loads should not be applied at the extremities of the trunnions which will tend to deflect and "squeeze" the bearing balls.

Radial or side loads on the nut can usually be accommodated but act to reduce life. If side loads cannot be avoided, a double-nut assembly with connecting flanges at the center can be used to spread out the effect of the load. Another effective method of avoiding side loading completely is through the use of secondary bar suports, *Fig.* 12, which assure concentric axial loading at the screw assembly. Combination end and side loads are not usually recommended, but may be permissible where the end load is small in relation to the side load.

Nut selection and mounting depend primarily on the physical characteristics of the load. Internal or external trunnion nuts connected to the load through gimbal type mountings are the most desirable. This combination eliminates the possibility of side loading on the nut as well as the danger of the balls being pinched under deflection. Where external guides, such as machine ways or cylinders for example, can be employed to prevent side loading, flange or threaded connections are usually satisfactory, *Fig.* 13. The plain nut is particularly suitable for sleeve or cradle type mounting arrangements. With the integral nut the ball circuit becomes an integral part of the driven machine member. This design involves the highest cost but is advantageous where compactness, light weight or appearance are important factors.

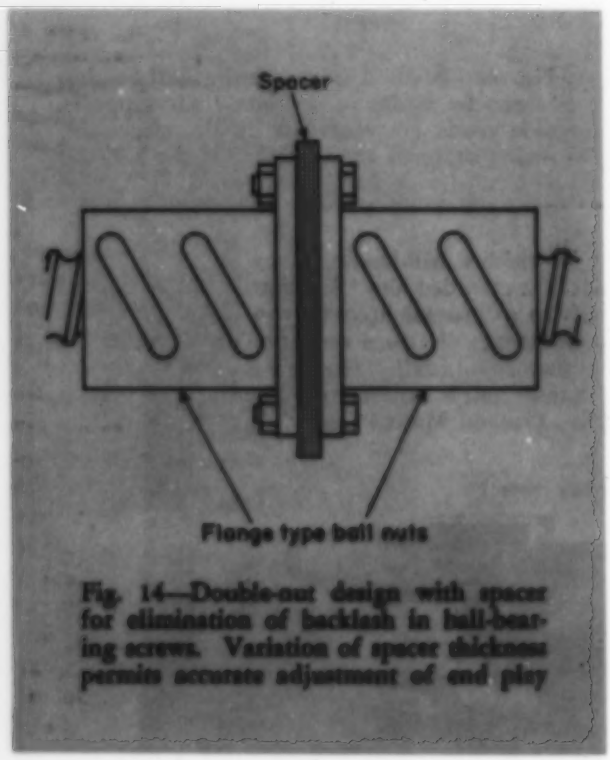


Fig. 14—Double-nut design with spacer for elimination of backlash in ball-bearing screws. Variation of spacer thickness permits accurate adjustment of end play

Backlash Elimination: A certain degree of end-play or backlash is inevitable in ball-bearing screw assemblies because of tolerance requirements on the bearing balls and the ball grooves in both the nut and screw. This end play usually never exceeds 0.005-inch but, where closer operating tolerances are required, can readily be reduced further by two techniques. In one method, selectively fitted oversize balls are used in the ball circuit. The second method employs two flange type nuts which are mounted flange to flange with a spacer separating them, *Fig.* 14. Precise adjustment of end play is achieved by regulating the thickness of the spacer.

Lubrication Requirements: Screw assemblies can be operated either dry or lubricated. Lubrication is generally recommended but is not necessary and will have little effect, if any, on efficiency or life. For operation under extreme high or low temperature conditions, or where dust, grit or abrasive particles are present, lubrication is usually impractical or perhaps even harmful, and should therefore be avoided.

Braking Methods: As a result of the inherent free-running action of the ball-bearing screw in either direction, the output screw member will have a tendency to coast under a dead load if either the screw or nut are free to rotate. For certain applications, such as aircraft landing gears, this action can be used to advantage and will permit a driven mechanism to complete part of its operational cycle without power. At the same time, however, several effective braking methods have been developed to control this action.

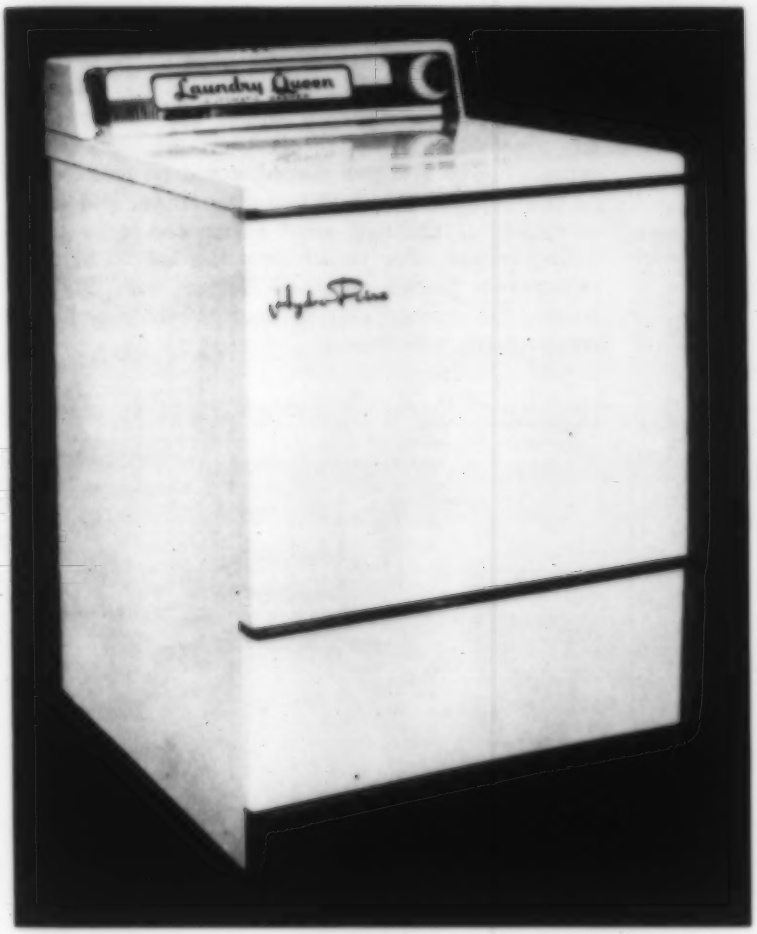
Where a nonreversing worm gear reducer is incorporated in the drive system, reverse rotation of the driven screw member is automatically prevented. Another method that has been used successfully with vertical load movements employs a ratchet-type friction brake on the nut. In operation, the ratchet action prevents "free fall' but the brake can be slipped to permit backing-off the nut. In such systems, a one-way clutch may also be used to serve the same function as the ratchet. Additionally, several commercial "no-back" devices are available.

To prevent overtravel of the nut or screw, pin-and-dog type stops are often used. In some cases, flat-faced stops with contact surfaces made of cloth and resin laminates have been employed to absorb the momentum of the nut.

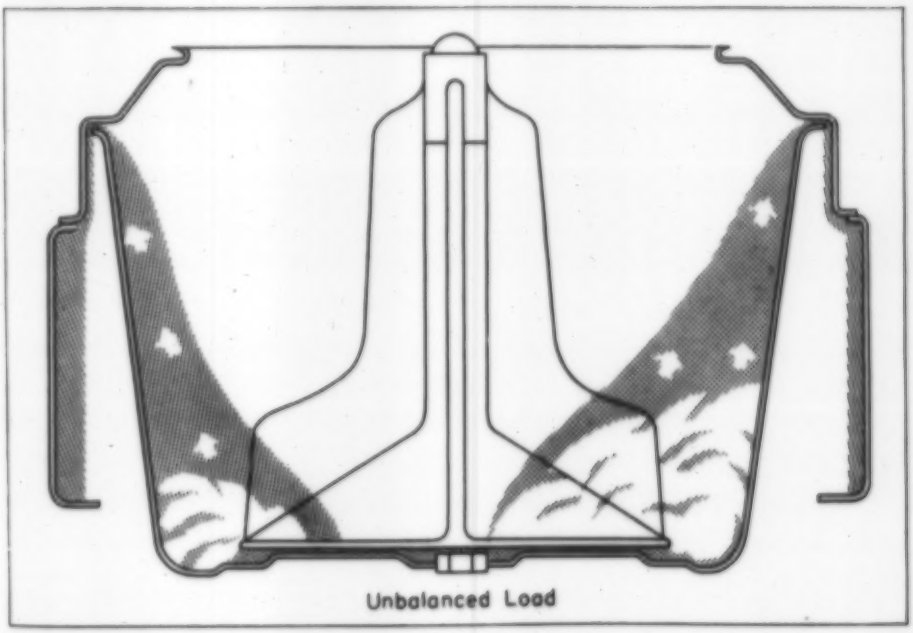
American industry has a feeling that with the help of today's science and engineering it can solve almost any problem. But we still face the fundamental problem of expaining what it is and does—of making our industrial mechanism really understood to million of Americans whose lives and future are bound up with its progress.—MALCOLM P. FERGUSON, *president, Bendix Aviation Corp.*

Contemporary Design

WASHER HAS AUTOMATIC DYNAMIC BALANCING



A UNIQUE tub balancing system known as Hydro-Poise permits spin drying at 750 rpm and other washing operations to be performed with virtually no vibration of the Laundry Queen washing machine. Bolting the machine to the floor is not required, and it is said that a five-cent piece will stand on edge on top of the machine during the entire washing cycle. All washing steps are controlled by a single dial which permits selection of any step of the full automatic cycle and repetition of any steps desired. Adjustments for water temperature and quantity are also provided. A pump with integral electric motor discharges water even to elevated drains. Complete washing cycle of the machine, made by Automatic Washer Co., includes agitator washing; spin and power spray rinse; flush rinse; agitated rinse; another spin and power spray rinse; and spin drying.

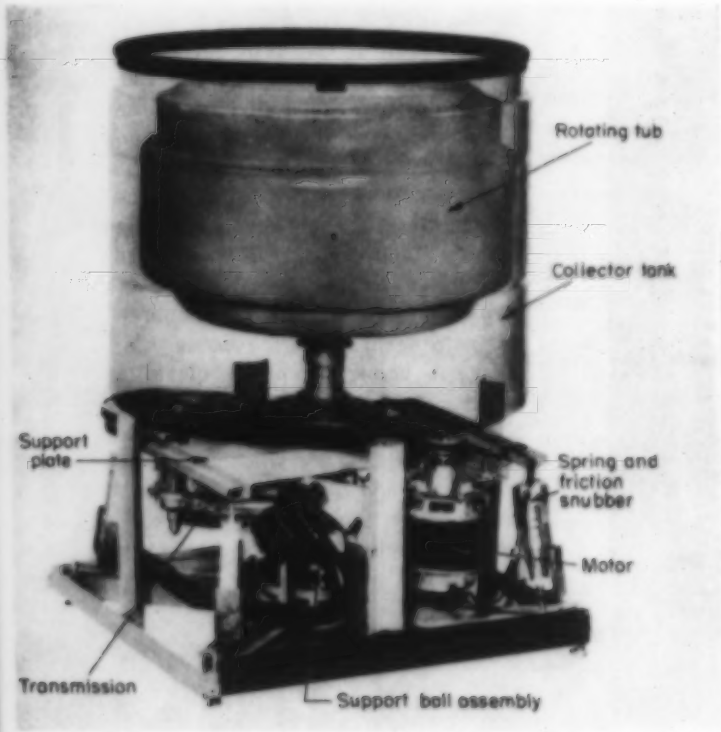


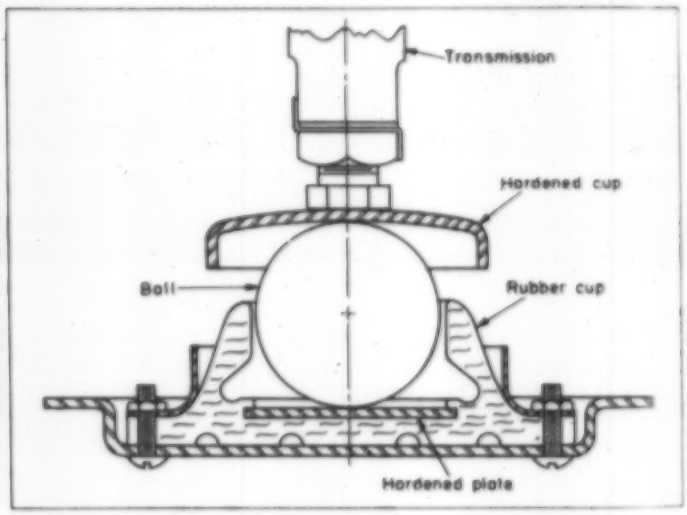
Moving parts of the machine such as motor, transmission and rotating tub are mounted on a support plate. The plate and other parts are in turn supported only by a single large ball mounted on the bottom frame of the machine. Four spring and friction snubber assemblies attach to the corners of the support-plate assembly to constrain its motion within desirable limits. Since a flexibly supported mechanism such as this tends to revolve around the common center of gravity of the mechanism plus its unbalanced load, the center of rotation of the tub plus an

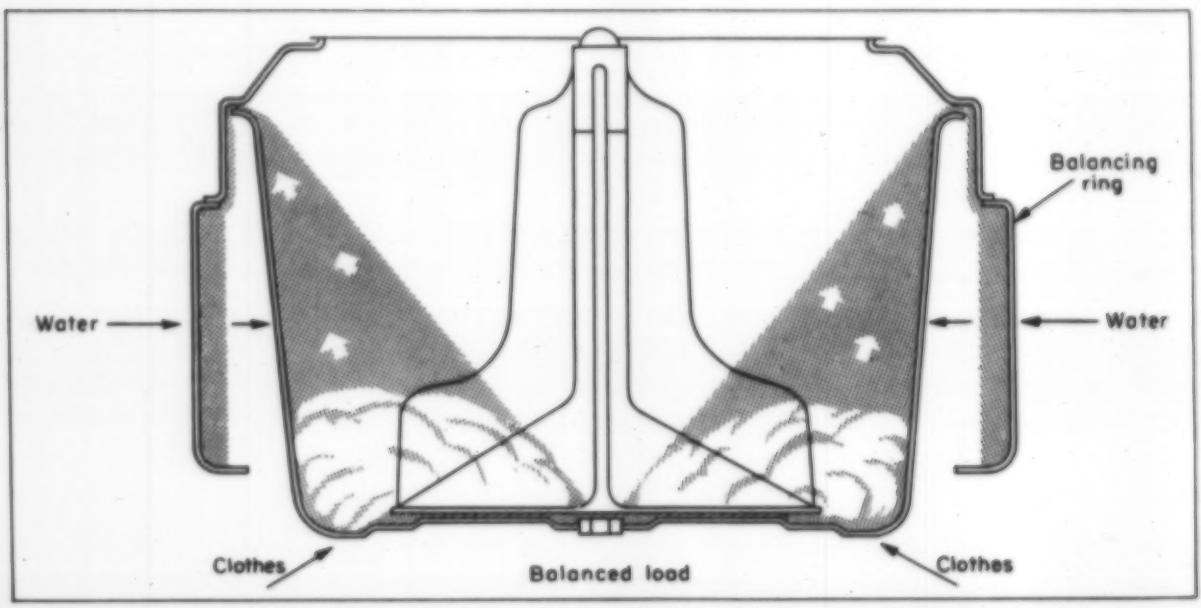
WASHER HAS AUTOMATIC DYNAMIC BALANCING

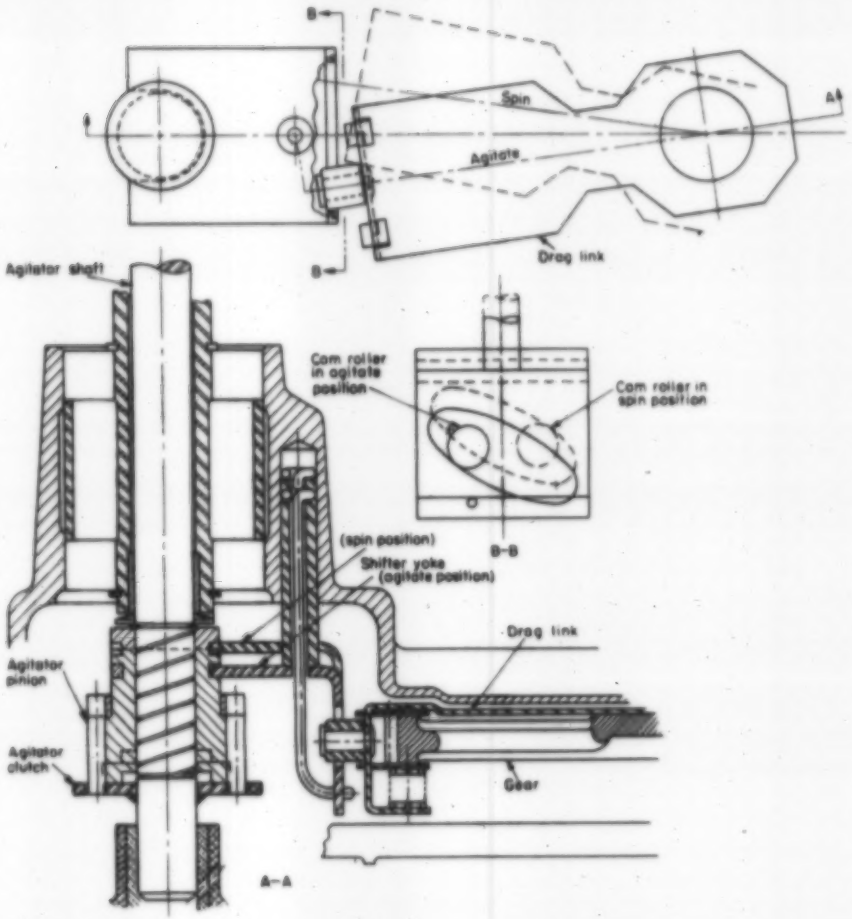
unbalanced load tends to move away from the tub axis in the direction of the heavier load. As this happens, centrifugal force, in its effort to move water in the tub as far away from the center of rotation as possible, causes more water to accumulate in the balance ring on the side opposite the heavier load. Dynamic balance of the rotating assembly results. Perforated baffles prevent surging of water in the balance ring.

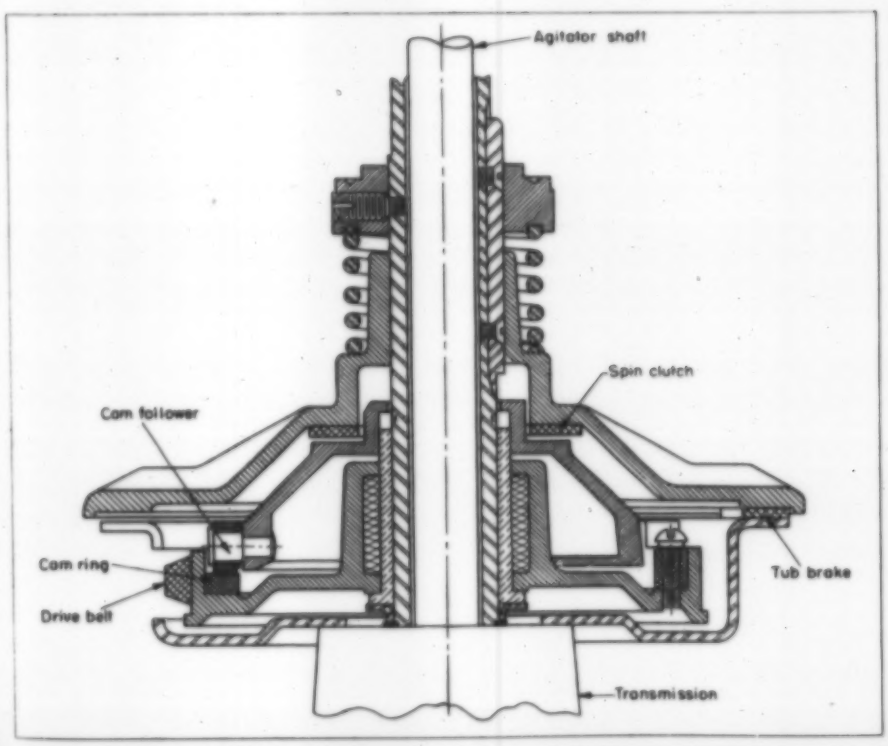
Vertical position of an unbalanced load determines the point about which tub and mechanism assembly attempt to pivot. Under certain conditions heavy reactive forces would be transferred to the support ball and machine frame and cause vibration, if the ball were restrained by a close-fitting socket. For this reason the ball is held between two plates, top and bottom and can roll within the rubber cup without creating any side force against the frame.











Agitation or spinning is automatically controlled by direction of motor rotation. When the motor runs in one direction, a drag link on a gear in the agitator transmission forces a shifter yoke down to engage teeth on the oscillating agitator pinion in holes in a plate welded to the agitator shaft. While agitation is in progress, the tub brake is set as shown, and the tub does not rotate. When motor rotation is reversed by the cycle timer and control switches, the gear and drag link rotate in the opposite direction to disengage the agitator clutch teeth. At the same time, the cam ring and support assembly — driven by the V-belt segment between the motor sheave and the transmission drive shaft— rotate, forcing the cam followers and supporting section to rise, contact the spin-clutch friction facings and disengage the tub brake. The tub then spins at 750 rpm.

Adjustable speed . . .

. . . has become a common and desirable design feature as demands for more versatile machines increase. This trend requires a thorough design knowledge of the various types of available systems and their characteristics.

To aid the designer in selecting the proper drive, *Machine Design* has programmed a comprehensive series of articles dealing with the various available systems. Companion guides already published cover adjustable-speed electric-motor drives (October, 1954), mechanical drives (April and June, 1955), and magnetic slip couplings (July, 1955).

This article . . .

. . . deals with both stepped and stepless methods of speed adjustment using positive-displacement hydraulic pumps and motors as the basic components of the system.

Design Manual

ADJUSTABLE-

By Keith A. Carlson
Associate Editor
Machine Design

ABILITY to vary rotational speed as desired is a must in the control of many machines. In certain other machines, speed control may be advantageous though not absolutely necessary. The prime mover, be it electric motor, internal combustion engine or turbine, may often be controllable to provide the required speed variation. In the event that the nature of the prime mover is such that its speed is not easily controllable an adjustable-speed transmission must be used.

Certain other circumstances may also make the use of a transmission advisable. For instance, operating speeds of internal-combustion engines can be varied over a range of 8 to 1 or less, usually. Cost of an electric motor having a relatively constant output speed plus the cost of an adjustable-speed transmission may be less than the cost of an adjustable-speed motor.

When faced with the problem of selecting an adjustable-speed system, the designer has three basic alternatives: Electrical, mechanical and hydraulic systems. The first two of these have been discussed in previous articles, "Adjustable-Speed Electric Motor Drives," October, 1954, and "Mechanical Adjustable-Speed Drives," April and June, 1954. This article will discuss adjustable-speed transmissions using a hydraulic fluid as the power transmitting medium.

Selection Factors: It is impossible to generalize to the extent of listing certain types of applications as being best suited to the use of hydraulic adjustable-speed transmissions. However, with a particular application in mind and a knowledge of the characteristics of different types of speed adjusting systems, a comparison can be made which will ordinarily result in the advantages of one system or another becoming quickly obvious. A check list, *Table* 1, of the factors to be considered is an invaluable aid in making such a comparison.

Transmission Types: All hydraulic adjustable-speed transmissions fall into two broad categories: Hydrostatic and hydrodynamic. *Hydrostatic* signifies that the transfer of energy is accomplished by the pressure of the fluid. *Hydrodynamic* trans-

SPEED HYDRAULIC DRIVES

What the designer should know about

Speed and torque ranges
Power output
Control systems
Reversing methods
Size and weight
Reliability

Table 1—Summary of Hydraulic Adjustable-Speed-Transmission Characteristics

Horsepower: Single hydraulic motors have outputs ranging from fractional to 4000 hp. Hydraulic transmission power output may increase or decrease as output speed increases.

Torque: Maximum available torque may remain constant or decrease as speed is increased. Maximum torques of hydraulic motors range from 60 to 566,000 lb-in. At stall or during starting a minimum of 90 per cent of maximum torque is delivered.

Speed: Maximum speeds of hydraulic motors range from 400 to 4500 rpm. Certain types deliver maximum torque at speeds from zero to maximum rpm.

Speed Variation: Stepped or stepless speed adjustment is possible either when operating or stopped.

Speed Regulation: Extremely accurate speed regulation as well as synchronization of hydraulic motors is possible.

Response Speed: In general, a hydraulic transmission will accelerate, decelerate and reverse faster than any other type of power transmission system.

Reversing: A reversing valve or reversal of pump output, provides fast, simple reversal while running.

Controls: Manual, power or servo controls can be used and are commonly available to provide constant speed or rapid speed changes as desired, with either constant or varying input speed.

Size and Weight: Weights of both pumps and motors range from approximately one to ten pounds per horsepower. Smaller sizes (below 5 hp) approach the higher figure. Units rated at more than 5 hp rarely exceed 5 pounds per hp. Actual volume is comparably low.

Maintenance: Inherent overload protection and the fact that moving parts are ordinarily adequately lubricated by the liquid being pumped insures long, trouble-free life. Largest single problem is piping leakage.

Efficiency: Overall efficiency of transmission circuits varies considerably. Circuit design and component design affect efficiency to a high degree. However, overall efficiencies may exceed 85 per cent.

Type of Service: Hydraulic transmissions are generally better suited to service where high shock loads, overloads, stalling and frequent speed changes or reversals are encountered than any other type.

Environmental Conditions: Normal ambient operating temperature range is 20 to 140 F. Special oils can extend this to −30 F to 170 F or higher. Only inherent danger is from ignition of hydraulic oil leaking from the system. Much effort is presently being expended on the development of nonflammable fluids. Properly designed systems are immune to atmospheric dirt, dust, etc.

Cost: Average cost of fixed-displacement pumps and motors is approximately $15.00 per horsepower. Variable-displacement units may be obtained for as little as $25.00 per horsepower. Cost of complete reversible transmissions may be as low as $40.00 per horsepower in larger sizes. However, small transmissions using variable-displacement motors or pumps may cost more than $150.00 per horsepower.

missions make use of the kinetic energy of a fluid in motion. By far the greater number of hydraulic transmissions are of the hydrostatic type and this article will be devoted to these.

Hydrostatic Transmissions: In general a hydrostatic variable-speed transmission consists of a pump and motor plus connecting piping and some control means. With few, if any, exceptions, pumps and motors are positive-displacement types.

Positive-displacement pumps are those in which the volume of oil displaced by the pump during one revolution is substantially constant regardless of pump speed or back pressure. Thus, pump output is almost directly proportional to its speed, *Fig.* 1. For a positive-displacement motor, the reverse is true. That is, speed is almost directly proportional to volume of fluid supplied, *Fig.* 2.

Common types of positive-displacement pumps and motors are gear, vane, radial piston, axial piston and screw types, *Fig.* 3. Any of these types can be used either as a pump or a motor with minor or no modification, *Fig.* 4.

It has been stated that pump output is theoretically constant and flow volume is directly proportional to speed or $Q = dn$, where Q = flow volume, cu in. per min; d = pump displacement, cu in. per rev; and n = rotational speed, rpm.

However, in actual practice, output volume of the pump or motor speed decreases slightly as back pressure increases, *Fig.* 5. This decrease in volumetric efficiency is primarily the result of oil leaking through the necessary running clearances. Since this is so, it is difficult to generalize to the extent of assigning a particular value of volumetric efficiency at maximum rated pressure to groups of machines such as vane, gear and piston.

Other departures from theoretical performance which are worthy of mention are, paradoxically, increases or decreases in output per revolution as speed increases at constant pressure. The apparent increase in displacement per revolution, *Fig.* 6, occurs because the slip volume is relatively constant at constant pressure and represents a smaller percentage loss as speed increases. Decreases in pump output per revolution as speed increases, *Fig.* 7, are the result of intake restriction and can be overcome by supercharging, that is using a small pump to supply oil to the inlet of the main pump at low pressure. Usually pump construction determines whether or not supercharging is necessary or economically justifiable. Certain pumps because of their design have relatively small curved internal oil passages and should, therefore, be supercharged to perform at maximum possible efficiency.

Pump intake piping should be kept as short and free of bends and elbows as possible to reduce effects of inlet restriction. Selection of the proper pipe size for intake lines is facilitated by the use

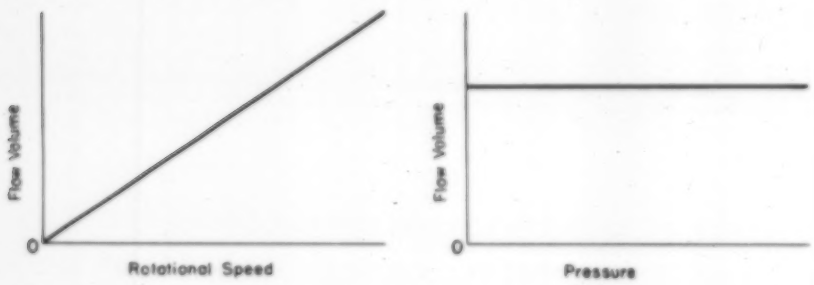


Fig. 1—Output of positive-displacement pumps is theoretically constant, regardless of back pressure, and proportional to speed

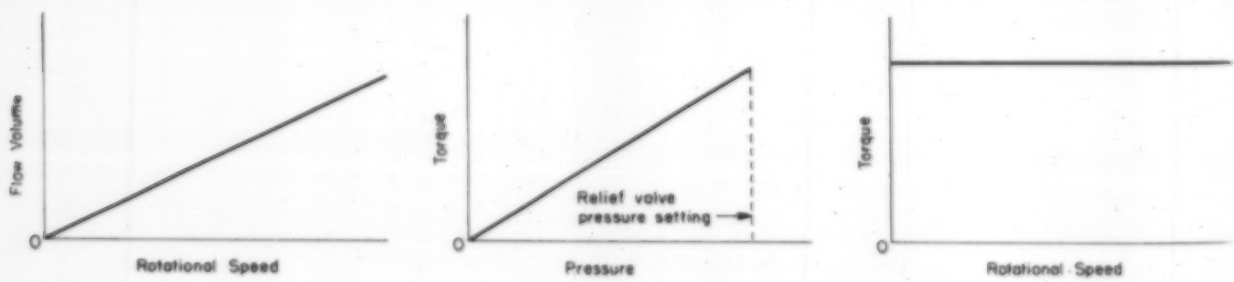
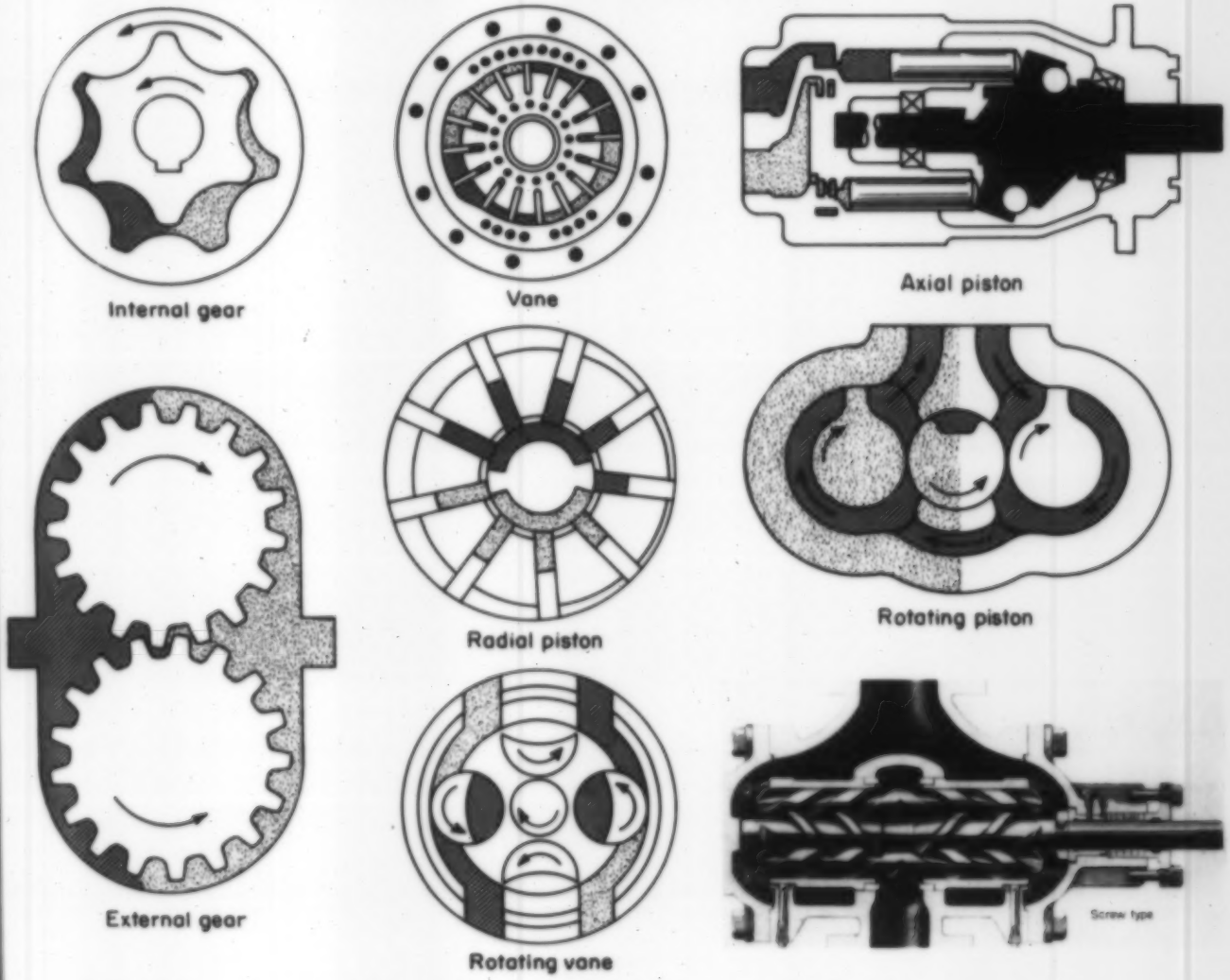


Fig. 2—Speed of a positive-displacement hydraulic motor is theoretically directly proportional to volume of liquid passing through it and is unaffected by torque loading of the motor. Torque output and system pressure are also directly proportional. Both torque and pressure are functions only of load on the motor and could increase to dangerous values if a safety or relief valve were not incorporated in the circuit. Maximum torque output of a fixed-displacement hydraulic motor is, therefore, constant at a value proportional to relief valve pressure, regardless of motor speed

Fig. 3—Construction of these common types of positive-displacement pumps and motors is similar in that liquid being pumped is effectively trapped and carried in the desired direction



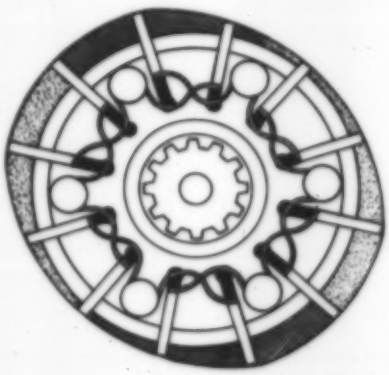


Fig. 4—Although a vane-type machine can be used as either pump or motor with no modification, mechanical means are used to hold vanes in contact with the cam ring of this vane-type motor. Centrifugal force performs this function in vane pumps and would in the motor, also, if the motor were operating at sufficient speed. The rocking beams increase torque exerted by the motor at low or zero speeds

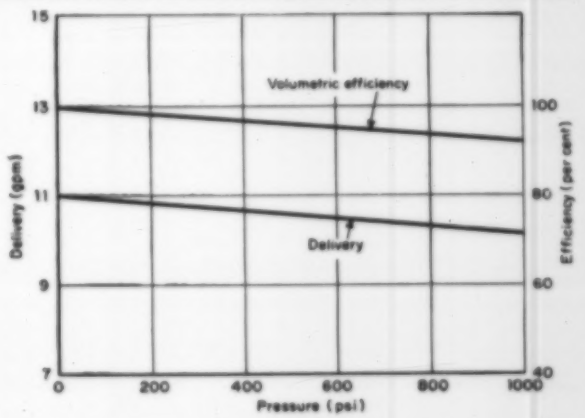


Fig. 5—Actual pump performance departs from the theoretical due to slip—leakage through the running clearances—as back pressure increases. Slip, of course, reduces volumetric efficiency. The same condition exists for motors and manifests itself as a reduction in speed as pressure increases despite constant flow volume. Characteristics shown are for a vane pump operating at 1200 rpm

JIC STANDARD SYMBOLS for HYDRAULIC CIRCUITS

LINES

Line, working	Line, pilot (L > 20W)	Line, drain (L < 5W)	Line, flexible
Connector (dot to be 3x width of associated line)	Direction of flow	Line, passing	Line, joining (tee, cross, etc) (dot to be 3 x W)
Reservoir (fluid tank)	Line, to reservoir Above fluid level Below fluid level	Manifold, vented	Plug or plugged connection
Testing station (gage connection)	Power take-off	Restriction, choke, fixed viscous	Restriction, orifice, fixed nonviscous

PUMPS

Pump, single, fixed displacement (PF)	Pump, single, variable displacement (PV)

MOTORS AND CYLINDERS

Motor, rotary, fixed displacement (MF)	Motor, rotary, variable displacement (MV)	Motor, oscillating (MO)
Cylinder single acting — Plunger type; Piston type	Cylinder double acting — Single end rod; Double end rod	

MISCELLANEOUS UNITS

Motor, drive, electric (ELEC MTR)	Heat exchanger (HE)	Intensifier (INT)	Accumulator (ACC)
Filter (FILT)	Strainer (STRN)	Pressure switch (PR SW)	Pressure gage
Spring	Shaft, rotating	Component enclosure	

VALVES

Valve, check	Valve, restriction, choke Variable viscous
Valve, restriction, orifice Variable nonviscous	Valve, basic symbol (insert model no for special valves) Method of indicating internal flow

VALVE EXAMPLES

Valve, manual shut off	Valve, maximum pressure	Valve, relief remotely operated	Valve, sequence directly operated
Valve, pressure reducing	Valve, flow control pressure compensated Viscous (PC) Non-viscous (PC)	Valve, shut off 2 position 2 connection	Valve, directional 2 position 3 connection
Valve, directional 2 position – 3 connection	Valve, directional 3 position – 4 connection Open center	Valve, directional 3 position – 4 connection Closed center	

METHODS OF OPERATION

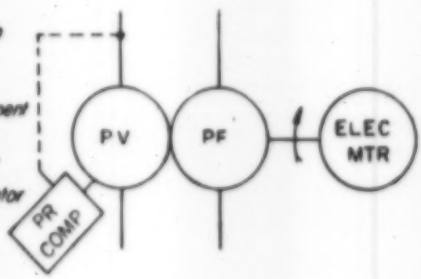
Control, basic symbol —	Control, centrifugal — CENT	Control, compensator — COMP
Control, compensator pressure — PR COMP	Control, compensator temperature — TEMP COMP	Control, cylinder — CYL
Control, detent — DET	Control, manual — MAN	Control, mechanical — MECH
Control, motor, electric — ELEC MTR	Control, motor, hydraulic — HYD MTR	Control, pilot, hydraulic — HYD
Control, pilot, air — AIR	Control, servo — SERVO	Control, solenoid — SOL
Control, solenoid hyd pilot operated — SOL HYD	Control, thermal — THERM	Control, pilot hyd differential area — HYD DIFF (S, L)

EXAMPLES OF COMBINATIONS

Pump, double—with electric motor

one fixed displacement

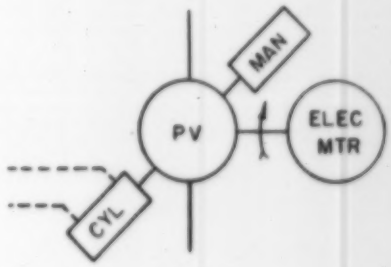
one variable displacement with pressure compensator



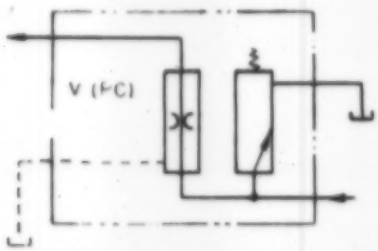
Pump, single- with electric motor

variable displacement

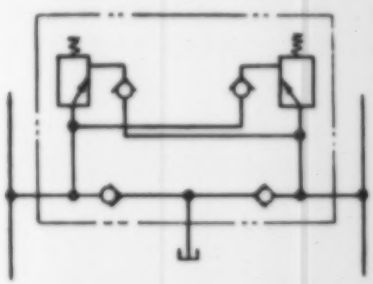
hand wheel and cylinder control



Valve, flow control and maximum pressure with compensator

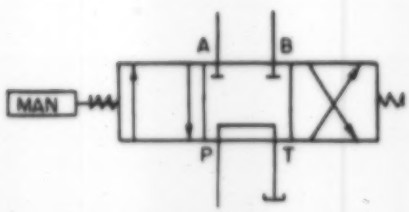


Valve, replenishing unit



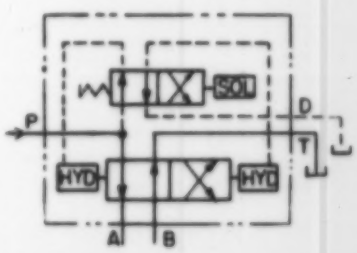
Valve, 4 way three position- spring centered manual control

P→T, cyl port blocked in center position



(NOTE symbol shown in center position)

Valve, 4 way two position spring offset solenoid control pilot operated



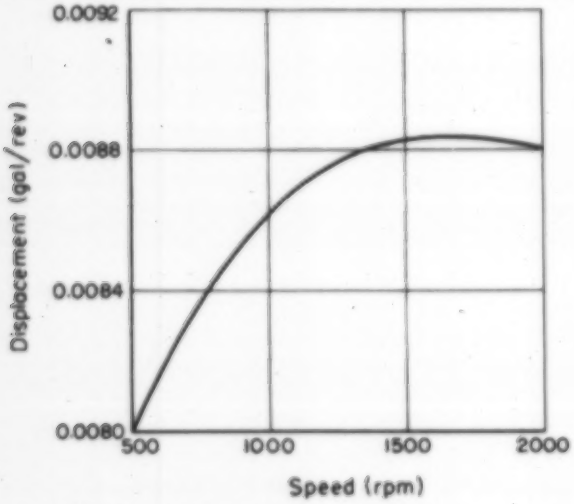


Fig. 6 — Output per revolution of a positive-displacement pump operating at constant pressure may sometimes increase because slip volume remains relatively constant and is, therefore, a smaller percentage of total volume at higher flow rates

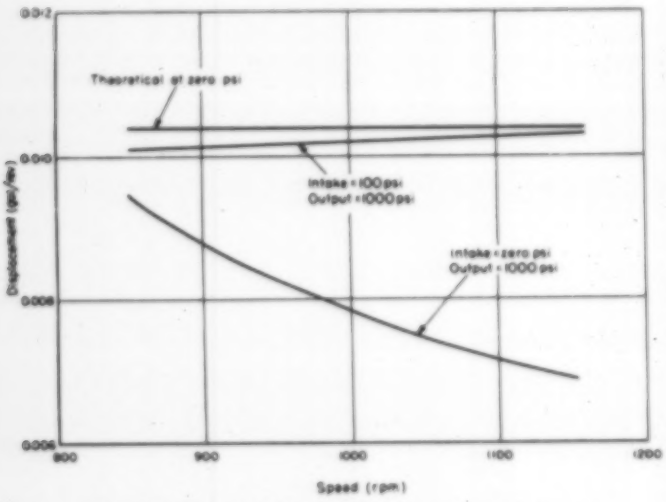


Fig. 7—Pump inlet restriction can cause a considerable decrease in allowable pump output per revolution as speed increases. Supercharging may be used to prevent this in the axial piston pump whose characteristics are shown

Table 2—Characteristics of Fixed-Displacement Pumps

	Drive Speed (max. rpm)	Pressure (max. psi)	Delivery (max. gpm)
Gear	865–8000	200–3500	0.3 –200
Gear, dual	1800–2000	1000–1500	1.75–9*, 3.2–50†
Vane	600–2000	2500	1.3 –60
Vane, two stage	600–1200	2000	2.5 –80
Vane, dual	1200–1800	1000–2000	1.5 –60*, 3.3–60†
Rotating vane	600–1750	300–750	15.2 –825
Piston	400–1800	3000–5000	5 –2300
Rotating piston	450–3600	1500–2000	27.6 –162

Based on a survey of representative commercial units.
*First section. †Second section.

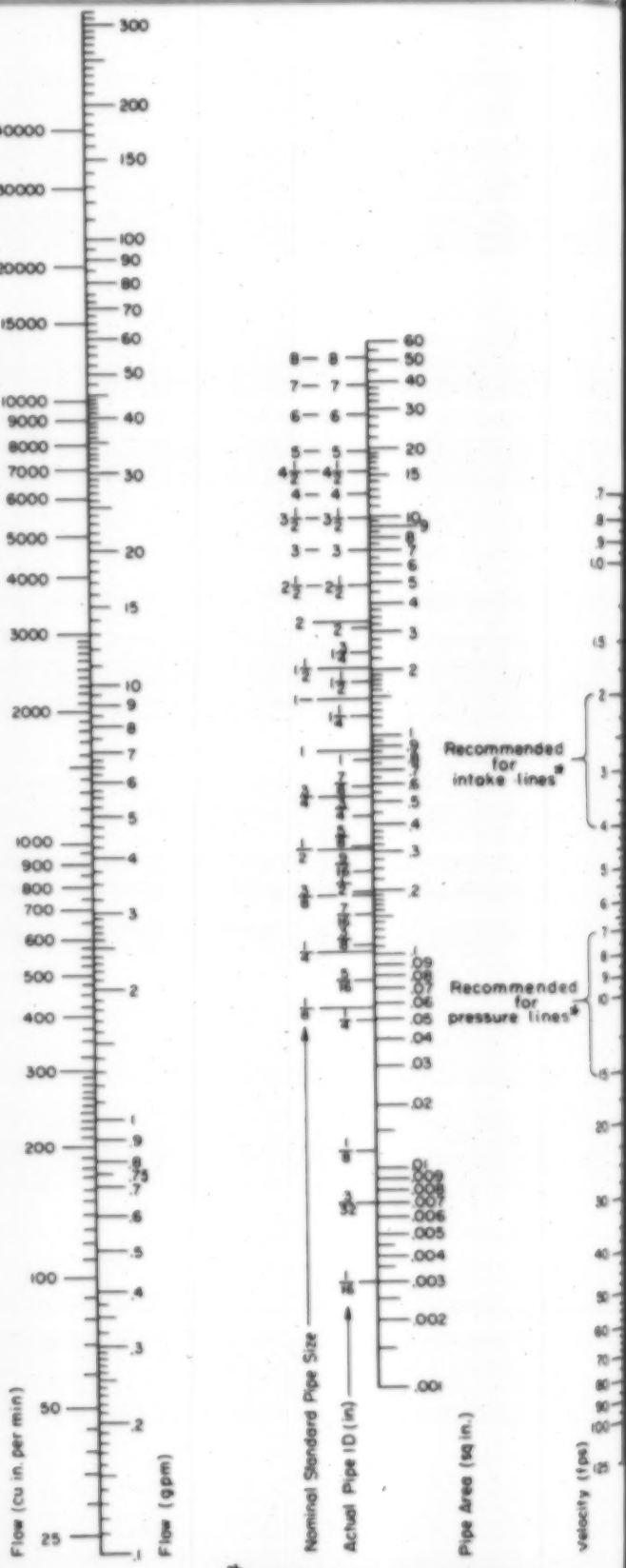

Flow (cu in. per min)
Flow (gpm)
Nominal Standard Pipe Size
Actual Pipe ID (in)
Pipe Area (sq in.)
Velocity (fps)
Recommended for intake lines*
Recommended for pressure lines*
*For 315 ssu max. viscosity oil at 100 F, operating between 65 F and 155 F

Fig. 8—A nomograph on which a straight line relates pipe size and flow volume to oil velocity can be used to select the proper size intake line for a pump, to prevent excessive restriction, as well as pressure lines

Table 3—Characteristics of Fixed-Displacement Hydraulic Motors

	Output Speed (min. rpm)	Output Speed (max. rpm)	Pressure (max. psi)	Torque (max. lb-in.)
Gear		1500–3600	1000–1500	60–3990
Vane		1200–3600	800–2000	143–14,400
Piston	1–50	400–3600	1500–3000	1575–566,000
Rotating vane	50	1200–2400	300–750	96–37,875
Rotating piston		1080–4500	1500–2000	6000–7100

Based on a survey of representative commercial units.

of a nomograph relating pipe size and flow volume to recommended inlet velocity, *Fig.* 8.

Speed of a hydraulic motor is theoretically directly proportional to volume of flow through the motor or, $n = Q/d$. The same relationship also applies to pumps. That is, output volume is proportional to input speed. Torque input of a pump or torque output of a hydraulic motor is theoretically a function only of the pressure drop across the machine or, $T = Cp$ where T = torque, lb-in.; C = a constant; and p = pressure, psi. In terms of pump or motor displacement, $T = dp/2\pi$. From these basic relationships, a formula for theoretical hydraulic motor power output or pump input corresponding to a given flow and pressure is $P = pQ/396{,}000$, where P = power, hp. This equation shows that, for the theoretical pump or motor, horsepower is entirely independent of liquid density or viscosity. Practically, however, slip in both pumps and motors does vary with viscosity, increasing as viscosity decreases. Manufacturers of hydraulic pumps and motors are usually quite specific regarding viscosities of fluids to be used with their products to obtain specified performance.

Five basic systems exist for varying output speed of a hydraulic adjustable-speed transmission, if the possibility of varying pump speed is ignored. These are:

1. Throttling circuits
2. Bypass circuits
3. Multiple pump circuits
4. Pump delivery variation
5. Motor displacement variation

In some instances, more than one of these methods may be combined to achieve the desired result. The first three of these methods are commonly used with fixed-displacement pumps, *Table* 2, and motors, *Table* 3.

Fixed-Displacement Pump and Motor Circuits

Throttling Circuits: These circuits, *Fig.* 9, are the most economical that can be used, insofar as first cost is concerned. However, an analysis of the functioning of the circuit will show that there are limitations.

Since the volume of oil passing through the motor will be constant unless a portion of pump output is bypassed through the relief valve, these circuits must operate at relief valve pressure to provide speed control. Therefore, horsepower input to the pump is constant regardless of horsepower output. Efficiency of this system is the ratio of horsepower out to horsepower in and can be very poor at speeds and torques appreciably below maximum.

For a given rate of speed, the setting of the throttling valve will vary with load on the motor. This and the poor efficiency at speeds below maxi-

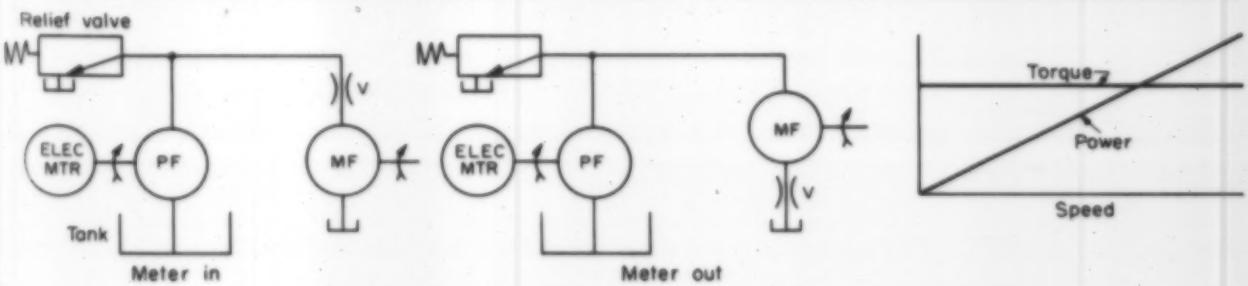
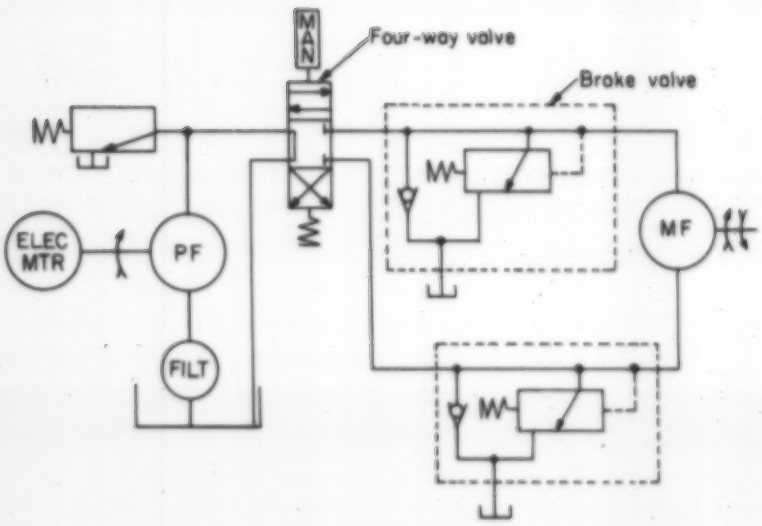
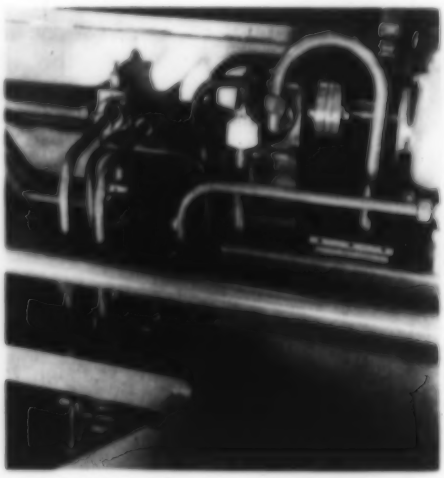


Fig. 9—Simplest fixed-displacement circuits for speed variation use only a pump, motor, relief valve and throttling valve. The throttling valve might be a needle, gate or any other type which acts as a variable restriction. The two circuits perform identically as long as the hydraulic motor drives the load. The meter out circuit resists "overhauling" or "overrunning" by the load, while such a load could evacuate the motor in the "meter out" circuit. Maximum available torque is constant while maximum available horsepower is proportional to speed. Theoretical efficiency of these circuits is the ratio of actual to maximum speed when motor torque requirement corresponds to relief valve pressure setting

Fig. 10—The bridge of this crane is powered by a fixed-displacement pump and motor combination using basically the same control circuit as that of *Fig. 9a*. Tapered spool of the four-way valve provides throttling for speed control during acceleration and deceleration. The four-way valve also permits reversing the motor. Spring return to the center position, where both motor ports are blocked, automatically brakes and holds the bridge. All valves, pump and reservoir are mounted at one end of the bridge. The motor is placed at the center of the bridge. This illustrates one characteristic of hydraulic transmissions which can be a decided advantage in many applications. The relatively small, light motor can be located where needed with the remainder of the equipment placed at some other, perhaps more convenient, location. Motor used in this application weighs approximately 75 pounds and develops 16.6 hp at 48 gpm and 800 psi





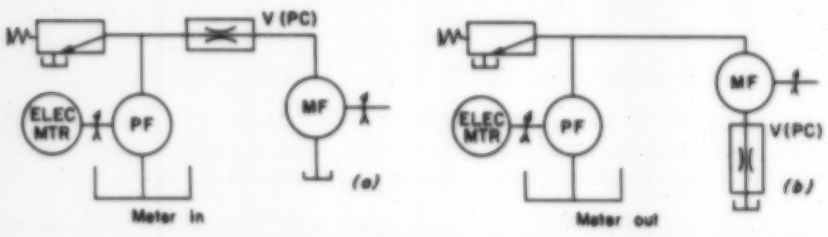
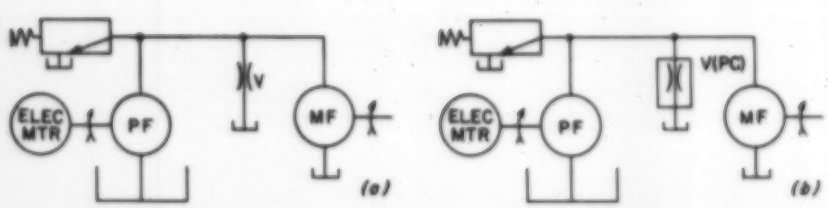


Fig. 11—One of the drawbacks of meter-in and meter-out circuits using simple throttling valves can be overcome by using a pressure-compensated flow-control valve. The pressure-compensated valve maintains a constant rate of flow and, therefore, motor speed despite pressure and motor load fluctuations

Fig. 12—Theoretical efficiency equal to the ratio of actual speed to maximum, regardless of torque, is obtained by using either a simple or pressure-compensated flow control valve in parallel with the hydraulic motor. Speed regulation in both circuits is not as good as the meter-in and meter-out circuits using pressure - compensated valves. Regulation of the circuit using the pressure-compensated valve is, however, the better of the two



mum make the use of these circuits attractive only when torque loads on the motor are nearly constant and operation will be at maximum speed during a very high percentage of the operating cycle, *Fig.* 10.

Use of a pressure-compensated, flow-control valve, *Fig.* 11, rather than the simple metering valve, in these same circuits results in a slightly improved transmission in some respects. However, the price of such a valve may be from eight to ten times that of the simpler valve.

Construction and operation of the pressure-compensated valve, are such as to maintain a constant rate of flow through the valve and, therefore, through the motor despite changes in the load on the motor. Output speed of the motor then remains constant despite variations in the motor load. Efficiency of these circuits is the same as those using a needle, gate or plug valve as a throttle.

Bypass Circuits: Speed control by means of either a simple throttling valve or pressure-compensated throttling valve in parallel with the motor in a fixed-displacement pump and motor transmission, *Fig.* 12, is also possible. These systems are usually called bypass circuits. In these sys-

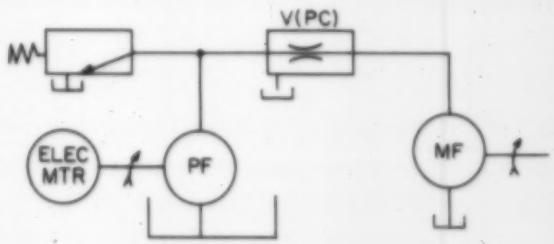
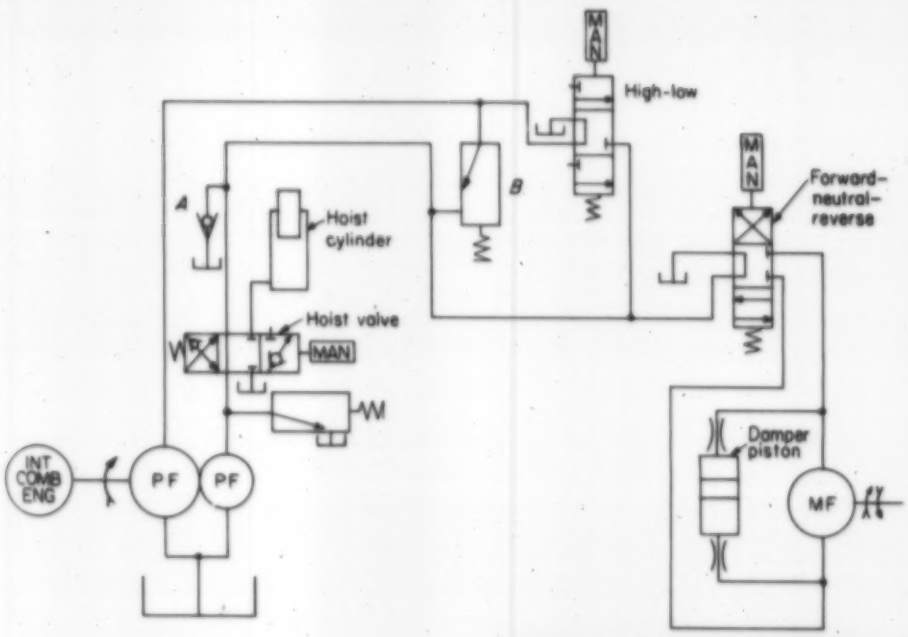


Fig. 13—A circuit using a three-port, pressure-compensated flow-control valve combines the desirable features of meter-in and bypass circuits



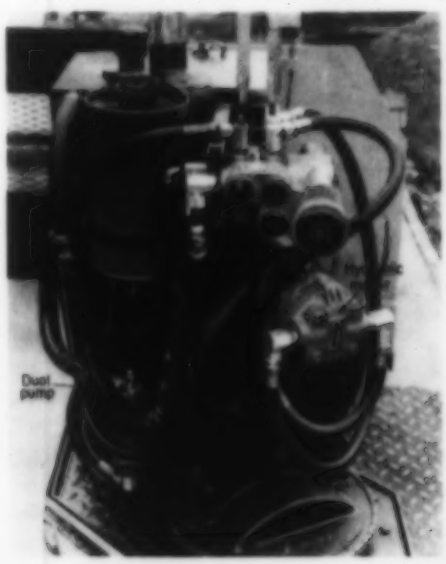
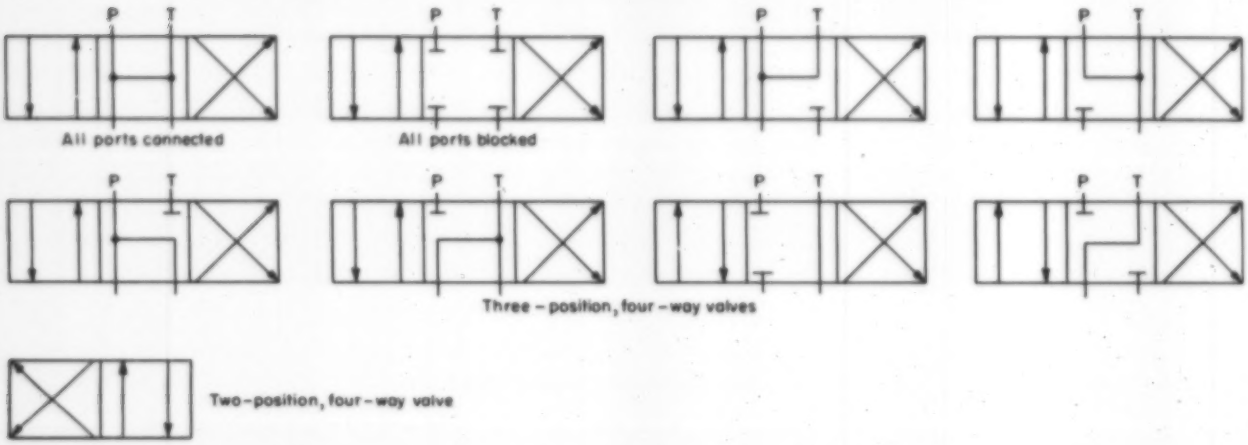


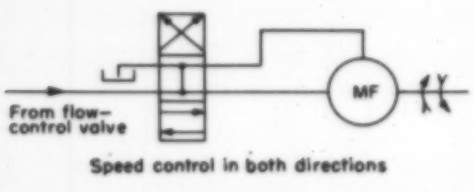
Fig. 14 — Two speeds forward and two in reverse are provided by this circuit using two fixed-displacement pumps. Used to drive a pallet handling truck manufactured by Colson Corp., the circuit also incorporates a cylinder for lifting and lowering the pallet platform. All three control valves are coupled to a single lever. Additional pressure after a shift to forward or reverse is made actuates the high-low valve which has a stiffer return spring than the forward-neutral-reverse valve. Lifting the lever actuates the lift cylinder. Check valve *A* allows the motor to pull oil from the tank when coasting. Relief valve *B* permits oil from the larger pump to flow to the forward-neutral-reverse valve while pump outlet is blocked by the high-low valve during a shift. Prime mover is a 6-hp, governor-controlled, aircooled gasoline engine. Maximum speed is 4 mph in either direction with a 2-ton load

tems, motor speed may be reduced without bypassing oil through the relief valve in the circuit. The significance of this is that the pump need not operate at relief valve pressure or pressure corresponding to maximum torque when less than maximum torque is required by the load. Theoretical hydraulic efficiency of these circuits is the ratio of actual speed to maximum speed regardless of output torque.

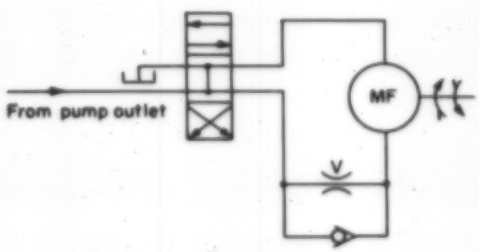
When the bypass valve in this circuit is an

Fig. 15—A number of variations are possible in the construction of four-way valves which may be used to reverse the direction of rotation of hydraulic motors. Three-position, four-way valves have a center or neutral position in which all ports may be blocked, all ports connected, or a combination of blocked and connected ports may be used. Some of the possible combinations of the circuits discussed so far and four-way valves are illustrated. Two-port pressure compensated valves may be substituted for the variable orifices shown in these circuits

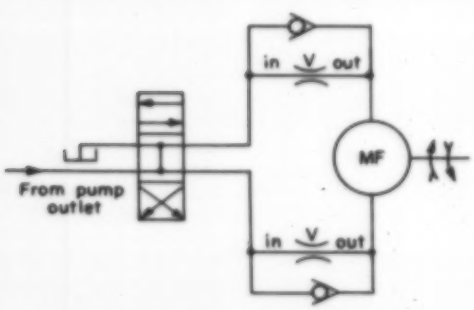




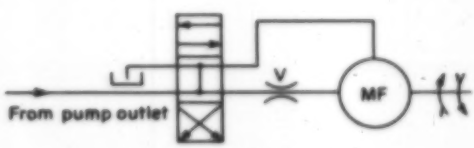
Speed control in both directions



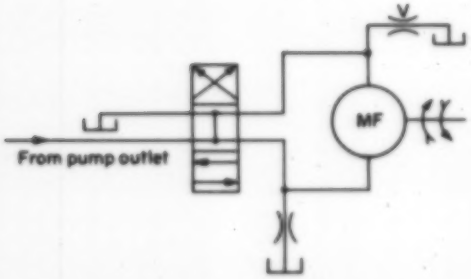
Meters in, one direction only. Free flow in reverse direction through check valve.



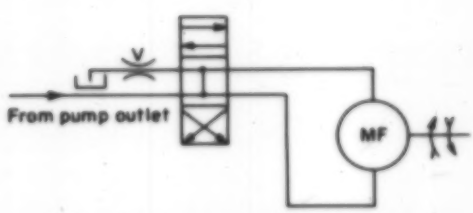
Permits setting of two different speeds one for forward and one for reverse operation. Meter in both ways or meter out both ways, depending on check valves.



Speed control in both directions. Meters out in one direction, meters in in the other.



Bypass control, both directions



Meters out for both directions of motor rotation.

ordinary throttling valve, *Fig.* 12*a*, variations in motor load will cause a comparatively large variation in motor speed. An increase or decrease in system pressure causes flow through the valve to change, thereby changing flow through the motor and motor speed.

Use of a pressure-compensated flow control valve, *Fig.* 12*b*, rather than the simple throttle valve will result in more accurate speed regulation in this circuit. However, some speed variation will occur as load changes because any change in pump flow will be manifested as a change in the volume of oil supplied to the motor. An increase in pump slip, for example, due to increased system pressure resulting from an increase in torque load would produce a reduction in motor speed.

Despite the possible variation in speed in bypass circuits, their efficiency when operating at torques lower than the maximum suggests that these circuits be given serious consideration for applications in which torque requirements may vary. However, the *meter-in* or *meter-out* circuits using a pressure-compensated flow-control valve provide better speed regulation than any circuit so far discussed.

Three-Port Bypass Circuits: Use of a three-port pressure-compensated flow-control valve results in a circuit combining the majority of the advantages of the meter-in and previously discussed bypass circuit, *Fig.* 13. The valve can be set to meter constant volume to the hydraulic motor regardless of variations in both input pressure and volume, assuming, of course, that the supply volume is in excess of the set output volume. Excess flow is bypassed to tank by the valve.

Theoretical efficiency of the circuit is the same as that of the bypass circuits. Price of the valve is approximately 33 per cent more than the two port type.

Dual Pump Circuits: Stepped speed control can be obtained by using more than one pump to supply oil to the motor. Two pumps having different volumes, for example, would with appropriate valving make three different output speeds possible, although they can also be used to supply only two, *Fig.* 14. Two of the available speeds would correspond to the flow volumes of the individual pumps and the third would correspond to the sum of the two volumes. Any of the previously discussed methods of flow control can be used in conjunction with multiple-pump circuits to provide stepless speed control between the discrete steps. More than two fixed-displacement pumps are rarely used in these circuits because the cost of the pumps and control would approach or exceed that of a variable-displacement pump.

Double pumps having a common housing, shaft and inlet port are commercially available. These units may incorporate integral relief valves. Units having separate inlet and outlet ports but driven by a common shaft are also available.

Reversing Circuits: Reversal of the direction of rotation of the hydraulic motor shaft can be very easily accomplished. A four-way valve is used to reverse the direction of fluid flow through the motor. This is directly comparable to using a double-pole, double-throw switch for reversing a direct-current electric motor. Valves may be either two or three-position types with a center or "off" position, *Fig.* 15. These four-way valves can be manually operated with detents in any or all positions or they may be constructed so as to be spring returned to a certain position whenever the operating lever, handle or pedal is released. Solenoids are also commonly used as operating devices.

Construction of certain four-way valves permits them to be used as flow-control valves providing usable speed control for accelerating, decelerating and positioning, *Fig.* 10.

Variable-Displacement Pump and Motor Circuits

Variable-displacement pumps and motors are positive-displacement types constructed in such a manner that displacement per revolution can be varied either during operation or when at rest. These units may be axial piston, radial piston or vane types, *Fig.* 16. Available units cover a wide range of speeds, capacities and pressures, *Table* 4. Many of the available variable-displacement pumps are constructed so that displacement may be adjusted from maximum to zero and then increased to maximum with flow occurring in the reverse direction while the input shaft rotates continually in the same direction.

Various types of manual and powered controls are available for changing the displacement of variable-displacement pumps and motors. The two basic mechanical controls are a push-pull rod or stem control and a handwheel control which turns a threaded rod to move the portion of the assembly

Table 4—Characteristics of Variable-Displacement Hydraulic Units

	Speed (max. rpm)	Pressure (max. psi)	Delivery (max. gpm)	Torque (max. lb-in.)
Pumps				
Vane	500–1800	1000–1250	5–70	.....
Piston	575–2000	1350–5000	2–2300	.....
Motors				
Piston	400–3600*	3000–5000	.....	1160–566,000†

Based on a survey of representative commercial units.
*Minimum speeds are ¼ to 1/5 maximum speeds.
†Minimum torque occurs at maximum speed and is ¼ to 1/5 maximum torque.

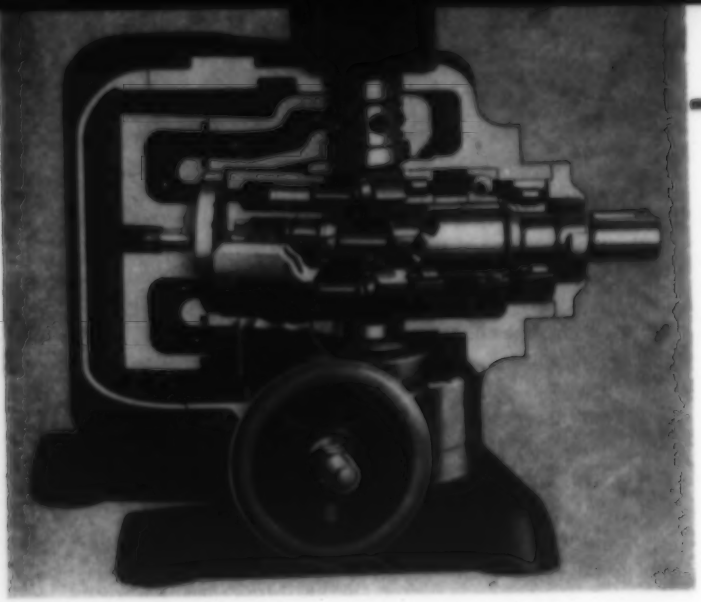
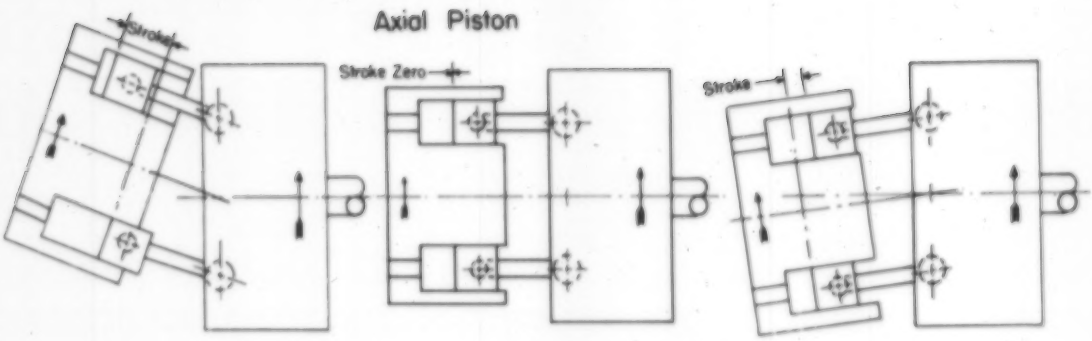
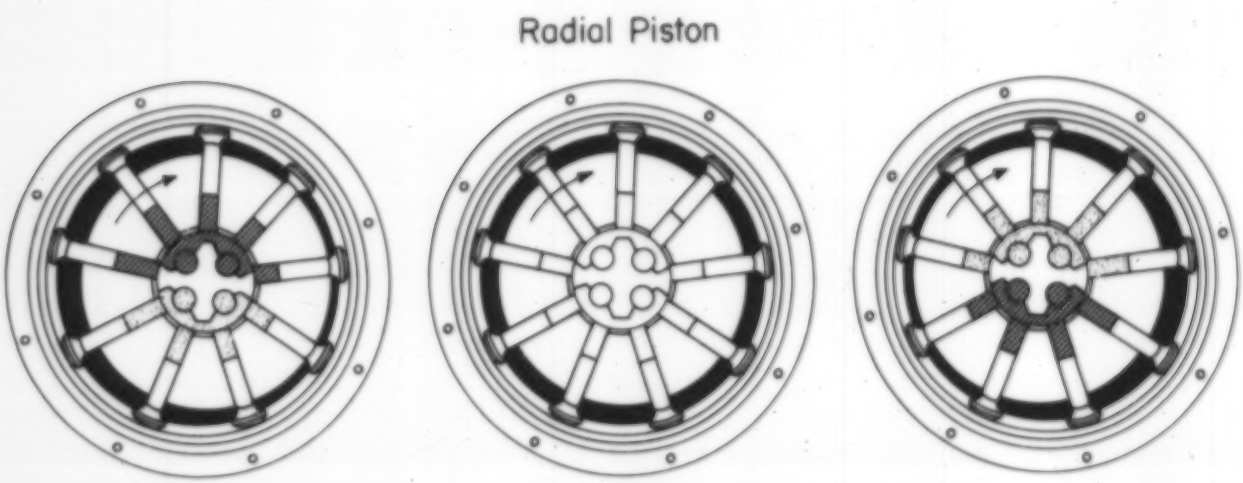
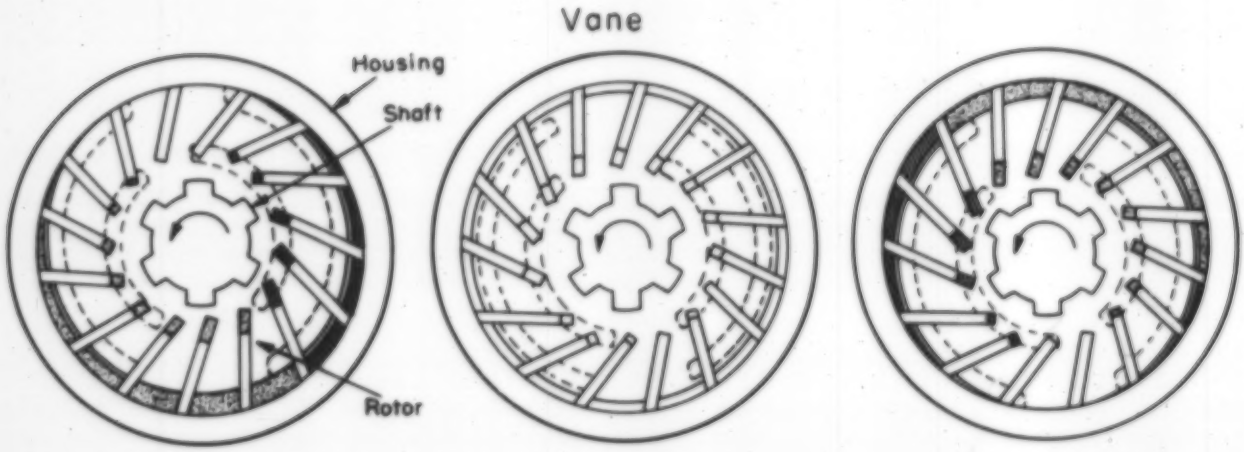


Fig. 16 — Variable-displacement pumps and motors permit variation in displacement per revolution. They may be vane, radial piston or axial piston types







which modifies displacement. Either of these two basic methods may be adapted to operation by electric motors, hydraulic motors, hydraulic cylinders or pneumatic cylinders. The power operating devices may, of course, be controlled by an operator through a valve or switch, or they can be made to respond to changes in torque load on the hydraulic motor, speed of the hydraulic motor or pressure in the system, *Fig.* 17.

There are three possible hydraulic adjustable-speed transmission circuits using a variable-displacement pump or motor or both. They are

1. Fixed-displacement pump and variable-displacement motor
2. Variable-displacement pump and fixed-displacement motor
3. Variable-displacement pump and variable-displacement motor

The third type combines the characteristics of the first two types.

Variable-displacement pumps and motors may be axial piston, radial piston or vane types. Fixed-displacement units used in combination with them are the same as previously discussed units. Since performance of transmissions using variable-displacement units is theoretically the same regardless of the type of construction, no attempt will

Fig. 17 — Both pressure-compensating and hydraulic cylinder controls are used in these circuits to vary speed as desired or hold output speed constant despite variations in load or input-speed. In circuit *a*, the pressure-compensating control, *PC*, attempts to vary output of the large variable-displacement pump as necessary to maintain constant pressure in the system. However, this would also tend to vary speed as load varies. The hydraulic control, *HYD*, is actuated by the pressure drop across the variable orifice which for any given setting is a function of the speed of the small fixed-displacement pump coupled to the motor. As motor speed tends to increase, increased output of the small pump results in a higher pressure drop across the orifice which reduces pump stroke to decrease speed. For a tendency to decrease speed, the operation is exactly reversed. Continuously variable speed control is obtainable by adjustment of the variable orifice. This circuit is not reversible as shown although with minor changes it could be. When the four-way valve is placed in its alternate position, fluid flow from the outlet of the motor is blocked at the valve. The relief valve opens and energy of the load is dissipated in pumping oil through the relief valve. Circuit *b* functions in a somewhat similar manner but does not provide quite as accurate speed regulation

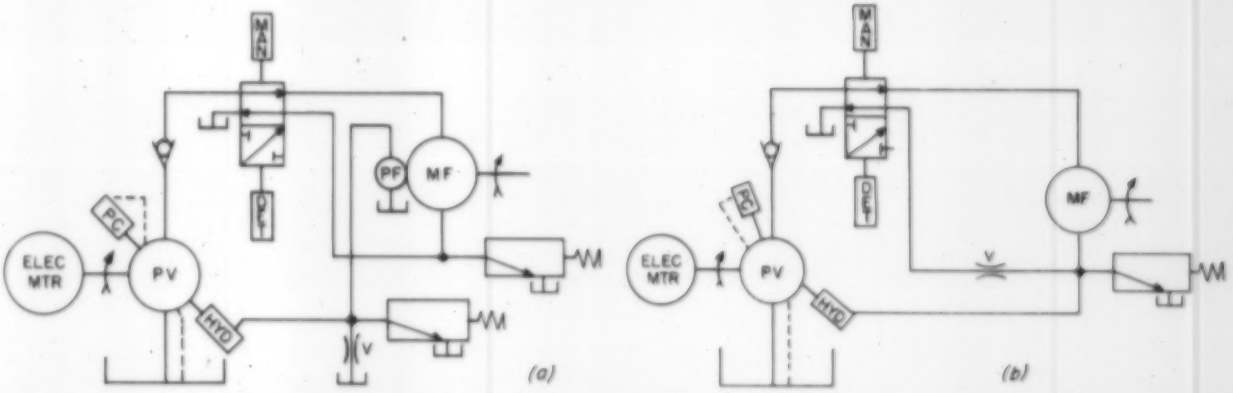
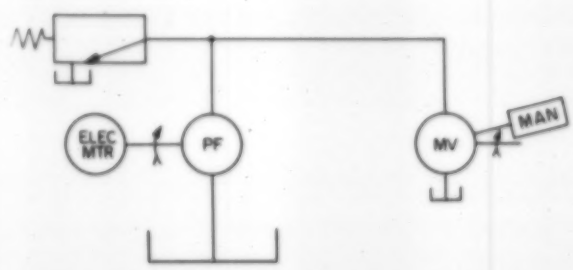
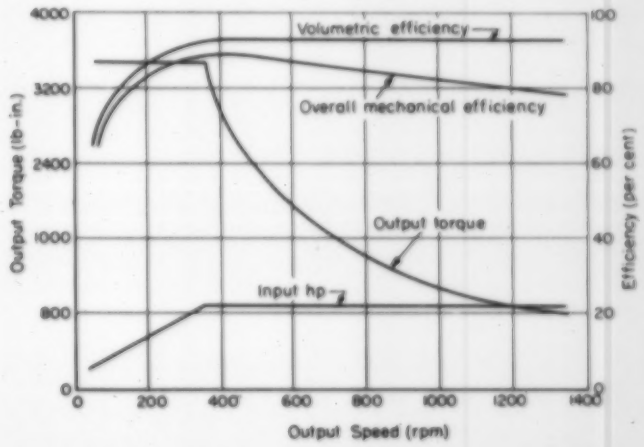


Fig. 18—A fixed-displacement pump driving a variable-displacement motor provides constant-horsepower variable-torque output. Maximum speed range with such a combination is a little greater than four to one. A four-way valve must be used for reversing





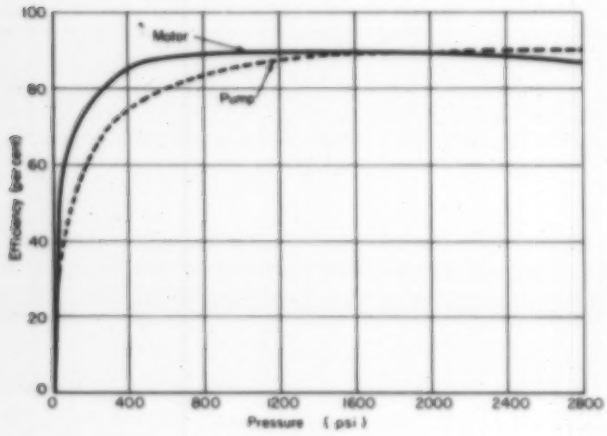
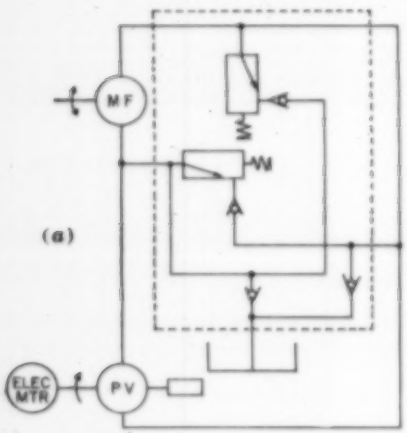
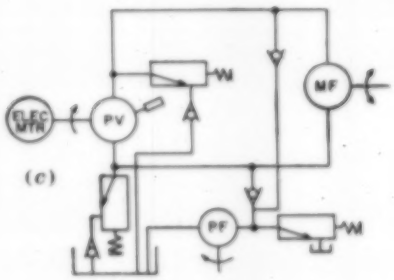
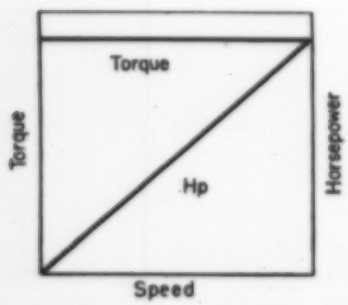


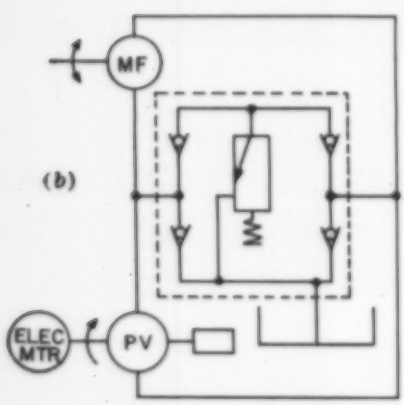
Fig. 19—Left—Curves of overall efficiency for commercially available axial piston pumps and motors show that efficiencies of hydraulic transmissions can be excellent when units are operated at or near optimum pressure

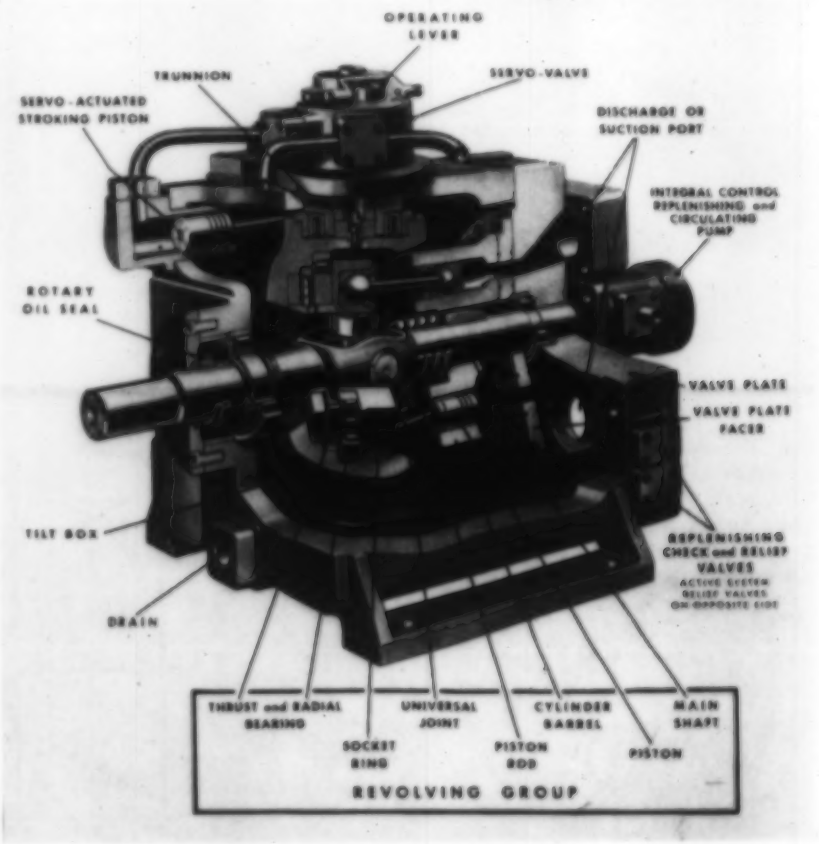
Fig. 20—Below—Circuits using variable-displacement pumps may be reversed by reversing pump output. Circuits must be closed as in *a* and *b*, unless a supercharger or replenishing pump is used, *c*, since pump inlet supply would otherwise have to come from the reservoir through the motor for one direction of rotation. Because *a* and *b* do not use supercharge or replenishing pumps, they are commonly called *gravity replenished* circuits and the reservoir must be placed above the pump. When an auxiliary pump is used to supply intake oil, *c*, it is possible to return oil to the reservoir. However, analysis of the supercharged circuit shows that the system is closed and no oil returns to the tank unless one of the relief valves opens. Components shown within the dashed lines are commercially available as unit assemblies and are called replenishing valves. Torque and hp characteristics are as shown







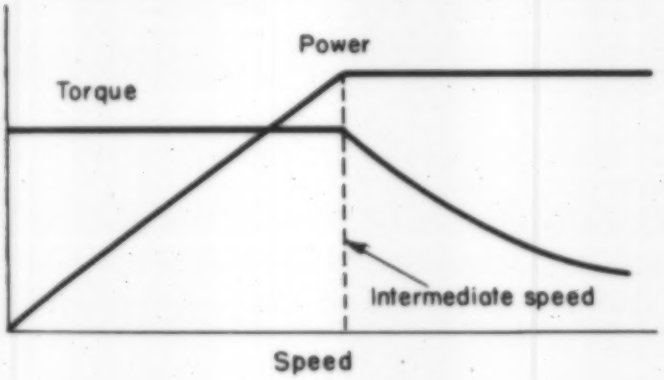




be made to discuss the performance of vane or piston units separately.

Fixed-Displacement Pump and Variable-Displacement Motor: Circuits of this type have a variable-torque, constant-horsepower output characteristic, *Fig.* 18. Consideration of the speed-torque curve, which is the same shape as a speed-displacement curve, shows that these motors cannot be reversed by varying displacement from positive to negative. That is, they cannot be reversed by changing the internal arrangement of the moving parts so oil flow in the same direction would produce reverse rotation. This is true because, as the curve shows, passing through the zero speed point to reverse would require infinite displacement of the motor, which is physically impossible. Although it is physically possible to adjust displacement to zero and then increase it in the reverse sense, this would theoretically mean passing through infinite speed. Reasons for not following this course of action are obvious, and stops are provided by the manufacturers of variable-displacement motors to prevent such an occurrence. Net result of these limitations is a maximum speed variation range of four or five to one for these circuits and the requirement of a valve for reversing.

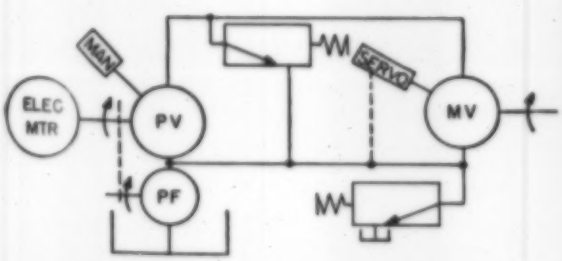
Fig. 21—Output characteristics of hydraulic transmissions using both variable-displacement pumps and motors combine characteristics of circuits using one or the other. Performance curves to the left of the intermediate speed line are those obtained by varying pump output only. Curves to the right of intermediate speed show the result of motor displacement variation. Intermediate speed corresponds to the maximum displacement setting for both pump and motor

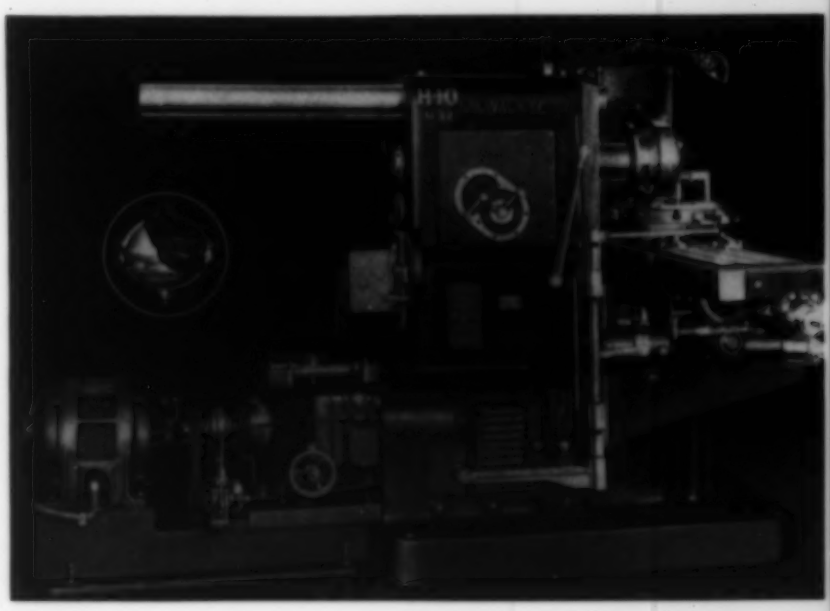


Efficiency of this circuit is theoretically 100 per cent. There are, of course, losses in efficiency for reasons previously discussed, but overall efficiency of these circuits may approach 90 per cent, *Fig.* 19. Suggested applications are those requiring the constant horsepower output provided. A common application is tension control when winding strip material onto rolls. As the diameter of the roll increases, a sensing mechanism varies displacement of the motor to decrease torque and increase speed of rotation of the roll. Thus tension and lineal speed of the strip are kept constant.

Selection of components for use in this circuit, as in other circuits, starts with the motor. With

Fig. 22—The circuit, used on the milling machine shown here, is almost identical with that of *Fig.* 20*c*. Some simplification is obvious. This is because the application calls for operation in one direction only. The servo control on the motor is actuated by a mechanical linkage from the machine worktable to automatically increase speed as the cutter moves to smaller diameter of the work piece shown in the small inset. A constant surface cutting speed is thus maintained. Manual control of pump output provides the correct speed which is then maintained



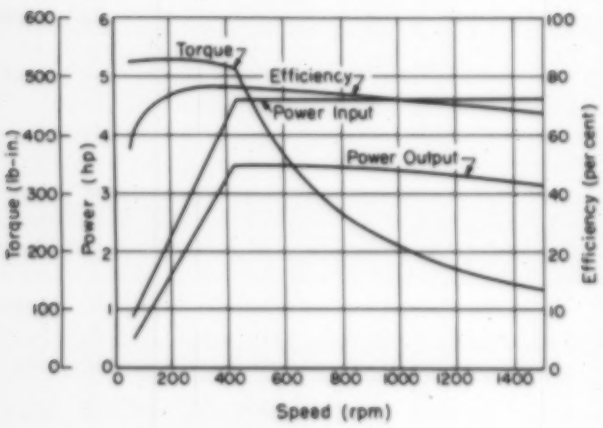


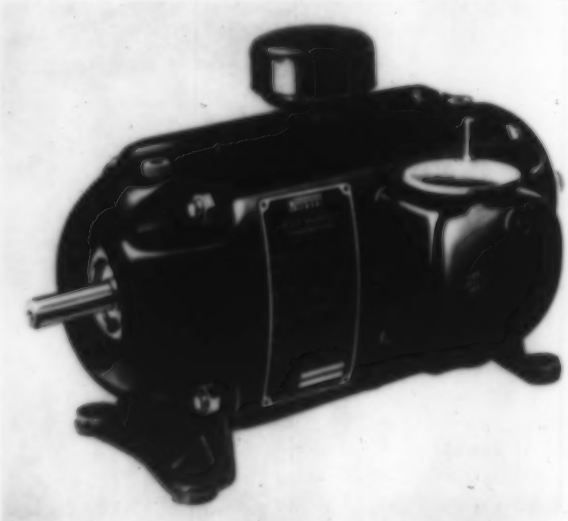
the required speed and torque of the load determined, a motor providing these characteristics is chosen. Weight and size will also influence motor selection and pressure rating. When the motor has been chosen, a pump is selected to provide volume corresponding to motor displacement at minimum motor speed and, of course, at required pressure.

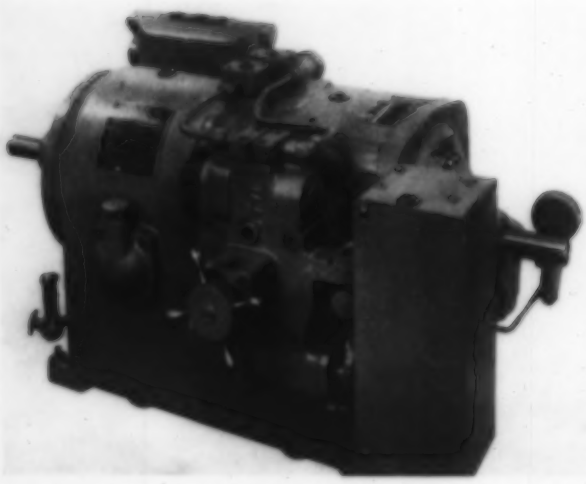
Variable-Displacement Pump and Fixed-Displacement Motor: These circuits, *Fig.* 20, have a variable horsepower and constant torque characteristic, *Fig.* 20, and provide reversing by pump stroke reversal. It will be noted that these circuits are of the closed type; that is, the oil in the system does not continually pass through the reservoir. The only purpose the reservoir serves is to replenish the supply of oil in the system when some is lost because of leakage.

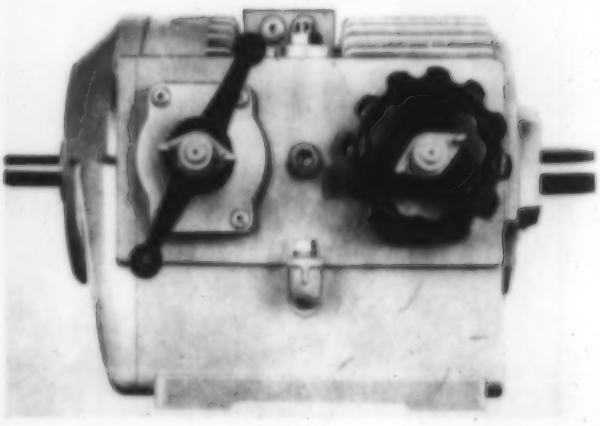
Component selection is based upon maximum torque and speed requirement of the load. The motor is selected to meet these requirements and the pump must supply the volume at maximum displacement corresponding to the required maximum speed of the motor. A curve of hydraulic motor input horsepower then supplies the rating of the electric drive motor required.

Fig. 23—Hydraulic transmissions using variable-displacement pumps or motors or both are available in a variety of sizes as packaged units incorporating all necessary valving and a reservoir. The unit at top right has maximum input and output speeds of 1800 rpm and maximum torque rating of 40 lb-in. Output speed can be varied from zero to maximum in either direction and input shaft rotation may be in either direction. Either a handwheel or servo control is available. Length, excluding shaft extensions is 10 9/32 inches, width including control box on side is 6 13/32 inches, and height including breather air cleaner mounted as shown is 7⅜ inches. Total weight of the unit is 14 lb. The 3.5-hp transmission unit, lower right, uses a variable-displacement vane-type pump and motor to provide the characteristics shown in the accompanying curves. Total weight of the unit is 324 lb. Length including shaft extensions is 25¼ inches; width with manual controls is 17 19/32 inches, and height is 13 11/ 32 inches. Nominally rated at 10 hp, the transmission at the lower left weighs 350 lb including oil cooler, filter and all necessary valving. Length, width and height are 35, 20 and 18 inches, respectively









Variable-Displacement Pump and Motor: Output characteristic of this circuit type is a combination of those of the two previously discussed circuits, *Fig.* 21. This particular combination is without question the most versatile of all variable-speed hydraulic transmissions considered in this article. It is at the same time the most expensive of the various types.

Circuitry is identical with those transmissions using variable-displacement pumps and fixed-displacement motors, with the exception of the substitution of the variable-displacement motor, *Fig.* 22. The designer has the option of constructing a transmission of this type from available pumps and motors or using an available unit, *Fig.* 23.

Additional Requirements

Within the broad potentials possible with hydraulic circuitry, a variety of special requirements can be met for particular applications. Two requirements—braking and synchronizing—are of sufficiently wide use to warrant at least brief discussion here.

Braking Circuits: Some method for safely reducing speed and stopping rotation is usually a necessary part of any hydraulic transmission. If the application is such that when the moving parts are at rest there will be no torque tending to rotate the motor, the brake system may be a completely integral portion of the hydraulic system, *Fig.* 24. Such a system will also be satisfactory, if a slight amount of creep is inconsequential. For applications in which there is a load on the motor and no creep can be tolerated, a mechanical brake which is actuated by the hydraulic system is satisfactory, *Fig.* 25.

Synchronizing Circuits: Many applications exist in which it is necessary to synchronize rotational speeds of a number of shafts either at the same speed or at speeds having fixed ratios to each other. Hydraulic adjustable-speed transmissions permit this to be done with an extremely high degree of accuracy.

For certain applications, two or more hydraulic motors connected in series, *Fig.* 26, might prove to be an adequate solution. However, there are certain drawbacks to this system which must be considered. Total pressure drop across the two

Fig. 24—This braking circuit is set up when the control valves of the circuits shown in *Figs.* 10 and 17 are placed in the *off* position. Inertia of the load drives the motor and the motor acts as a pump. Kinetic energy of the load is dissipated in pumping the hydraulic fluid through the relief valve. Retarding torque is equal to the torque rating of the motor at pressure equal to relief valve setting pressure. Braking may also be accomplished by reversing direction of flow from pump to motor in circuits such as those shown in *Fig.* 20. Flow reversal is the same as blocking flow, and the circuits of *Fig.* 20 function in the same manner as the circuit shown here until enough of the energy of the load has been dissipated to permit reverse flow and rotation

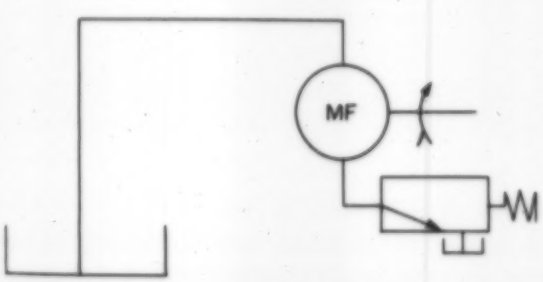


Fig. 25—Positive holding of loads on a hydraulic motor when not rotating must be supplied by a mechanical brake. A spring-applied brake which can be released by hydraulic pressure will often fulfill the necessary requirements. A valve may be used as shown to release pressure and apply the brake or the brake might simply be connected to the line feeding the motor. Other circuits using the same basic system, of course, are also possible

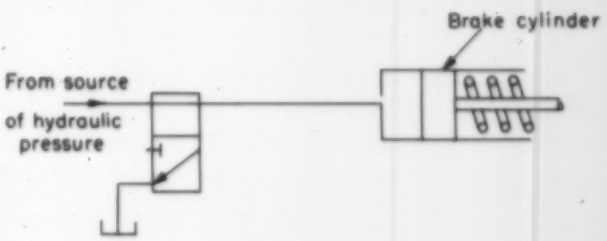
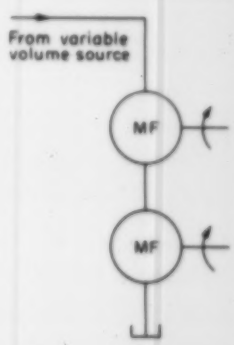


Fig. 26—Hydraulic motors in series will theoretically operate at equal speeds or speeds having a fixed ratio to each other. Practically, however, speeds of two or more motors in series might vary somewhat as pressure varies because of differences in slip characteristics



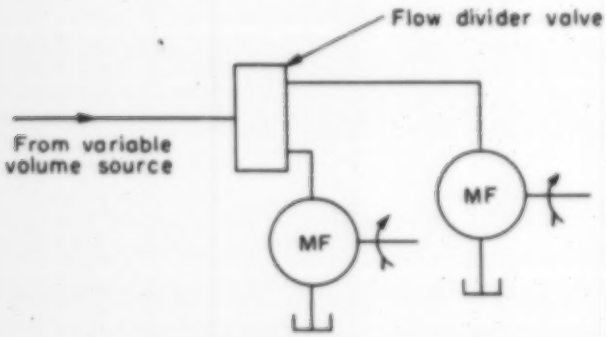


Fig. 27—A flow divider valve may be used to provide fairly good synchronization of hydraulic motors in parallel. All other things being equal, the parallel circuit requires only half the total pressure from the pump but twice the volume. Speeds of the two motors may depart from the theoretical for the same reasons as those in the series circuit, *Fig.* 26

or more motors will be the sum of the normal pressure drop across each. The significance of this is that total pressure requirement for a series of motors could be excessive. Additionally, slight differences in characteristics of the motors might not provide extremely accurate synchronization over a wide speed range.

Another system which can be used for synchronizing two motors, *Fig.* 27, employes a flow divider valve which automatically compensates for variations in flow resistance of two parallel branches. Flow divider valves may divide the input flow into two equal output volumes or into two volumes having a fixed ratio.

Various other systems exist for synchronizing speeds using hydraulic pumps and motors. Many of them use variable-displacement pumps with automatic speed regulating systems such as that of *Fig.* 17. Individual circuits of this general type may be hydraulically interconnected to give accurate synchronization over a wide range of speed variation.

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De Laval Steam Turbine Co. ..... Trenton 2, N. J.
The Denison Engineering Co. (*Fig.* 16) ..... Columbus 16, O.
Dudco Div., The New York Air Brake Co. ..... Hazel Park, Mich.
Eastern Industries Inc. ..... Hamden 14, Conn.
Ford Instrument Co., Div. Sperry-Rand Corp. ..... Long Island City 1, N. Y.
General Electric Co. ..... Schenectady 5, N. Y.
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Greer Hydraulics Inc. ..... Brooklyn 15, N. Y.
The Hydraulic Press Mfg. Co. ..... Mt. Gilead, O.
Hydreco Div., The New York Air Brake Co. (*Fig.* 14) ..... Cleveland 17, O.
Logansport Machine Co. Inc. ..... Logansport, Ind.
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Superdraulic Corp. ..... Somerset, Ky.
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Viking Pump Co. ..... Cedar Falls, Iowa
Waterbury Tool Div., Vickers Inc. (*Figs.* 19, 20, 25) ..... Waterbury, Conn.

They Say . . .

"According to Webster, design is to produce a plan. This would seem to involve mental logic.

"That which exhibits the spirit and faculty of an artist—Webster again—is styling. In short, an appeal to the senses. Styling denotes the niceties of proportion, the flow of line, rhythm, yes, even the swing of the hips.

"Industrial design is a composite of design and styling which has a selling-satisfaction-profit motive behind it. Its purpose is not to raise the esthetic taste of the purchaser or user, although this may indeed be a by-product. The arts have been used to further the ends of religion; they have been used to caricature politicians. Business uses the arts to sell merchandise at a profit." — J. MCLEOD LITTLE, *J. M. Little and Associates*

"A great attribute of the engineer's job is 'truth.' The engineer is successful because he has and uses a self-correcting philosophy of continually searching with reason and integrity for more truth. Engineers increase their fund of knowledge by the use of a meticulous procedure which they have carefully devised. Basically this procedure begins with a systematic investigation of a very small area. Very careful planning, open-minded experiments, and honest analysis of the results of the investigation are the methods by which the engineer increases his scope of knowledge within an area."—JAMES A. FLINT, *vice president in charge of engineering, Jeffrey Mfg. Co.*

Applying basic number theories to the design of drive systems with

IRRATIONAL SPEED RATIOS

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ANALYSIS of rotational speed-changing mechanisms in the light of the number theories of mathematics offers a fresh insight into the problem of obtaining specific ratios between input and output shaft motions. If the desired speed ratio is a whole number (integer) or a rational number (the ratio of two integers), it can be achieved exactly with toothed gears. With such drives, the speed ratio is usually determined by the ratio of the numbers, which must be integers, of teeth on the gears.

When the desired speed ratio is not a rational number, it is sometimes sufficient if the actual speed ratio is a close, but not exact, approximation to the design value. However, there are many possible applications for a mechanism with an exact relation between input and output shaft speeds that is not a rational number.

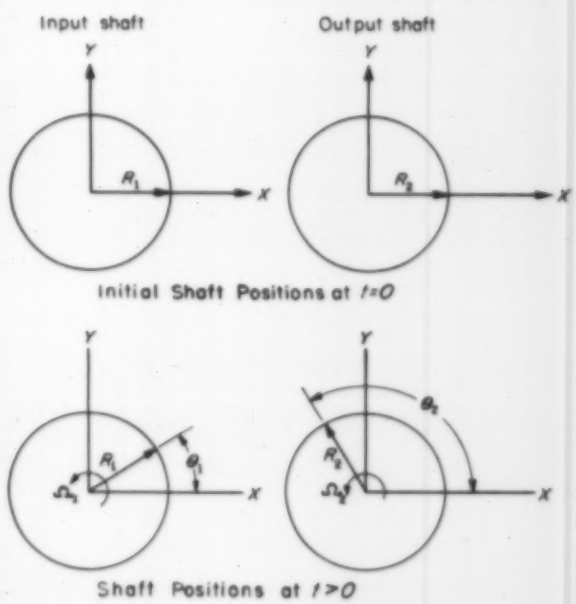
Thus, the question arises, "Is it theoretically possible to construct a positive drive mechanism with a speed relation equal to an irrational number?" Going one step further, "Can the special irrational numbers known as transcendental numbers be used?" Transcendental numbers are especially intriguing because they include the two numbers π and e which occur so often in engineering practice.

It is the purpose of this article to investigate the theoretical possibility of building an "irrational speed-changing mechanism." Primary emphasis is on positive drive devices, although friction drives and electromechanical devices will also be considered.

Although the previous questions were prompted by considerations related specifically to speed changers, they also apply to systems with input and output quantities other than angular position and velocity. However, as a first step towards understanding the implications of an irrational input-output system, this discussion has been limited to angular position and velocity as the pertinent quantities. Many of the conclusions can be extended to other systems.

Because of the properties of irrational numbers, mechanisms with these characteristics would have special applications in computers, lapping ma-

Fig. 1—Graphical representation of position and velocity relationships in a typical drive system. Relationships are defined by Equations 1 to 4



chines, coding equipment, and many types of industrial machinery.

The positive drive mechanisms under consideration here obey the following position and velocity relationships between output and input shafts, *Fig.* 1:

$$\theta_2 = K_t\,\theta_1 \quad \ldots\ldots (1)$$

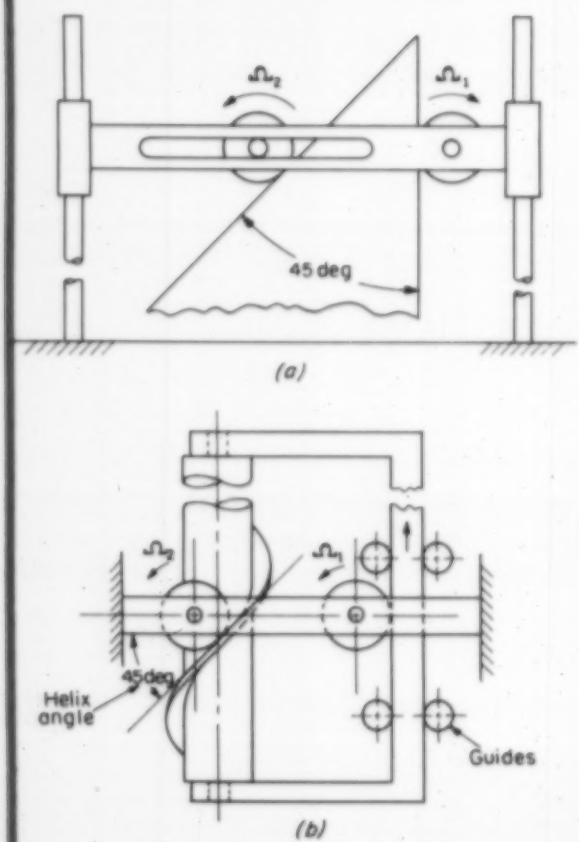
$$\Omega_2 = \frac{d\theta_2}{dt} = K_t \frac{d\theta_1}{dt} = K_t\,\Omega_1 \quad \ldots\ldots (2)$$

where θ_1 and θ_2 are angular positions of radii on the two shafts, in radians, and $\theta_1 = \theta_2 = 0$ at $t = 0$; t = time in seconds; Ω = angular velocity in radians per second; and K_t = speed ratio.

Thus, both angular position and angular velocity of the output shaft are related to the corresponding input quantities by the speed ratio, K_t.

In any linkage or mechanism, two types of errors may exist: (1) a mathematical or inherent error and (2) a manufacturing error due to the lack of absolute precision in any machining or fabricating process. This discussion is concerned primarily with the possibility of constructing speed changers which satisfy Equation 1 with no mathematical error. Fabrication errors, though all important in practice, will not be considered.

Fig 2—Mechanisms with algebraic irrational speed ratio, $\Omega_2 = \sqrt{2}\,\Omega_1$, showing, *a*, basic arrangement in which driving surfaces can be of tooth form and, *b*, alternative arrangement



A mechanism with no mathematical error is defined as a positive drive for which all the dimensions, angles, and other geometry determining K_t can be constructed with a unit of length, a straight edge and a compass, each instrument having perfect precision.

Mechanism Characteristics: The properties of mechanisms with irrational and transcendental speed ratios are determined by the properties of these special classes of numbers.[1,2] From the characteristics of the various classes of real numbers, outlined in *Properties of Real Numbers*, it can be seen that if K_t is an irrational number the resulting speed changer will have certain properties that differ from the case when K_t is integral or rational.

Nonrepetitive Coincidence: From Equation 1, it can be shown that the two radii defining angular position will be parallel and unidirectional (i.e., will coincide if the shafts are concentric) whenever

[1]References are tabulated at end of article.

Fig. 3—Mechanism with speed ratio equal to the transcendental number π. If $D = L$, then $\Omega_2 = \pi\Omega_1$

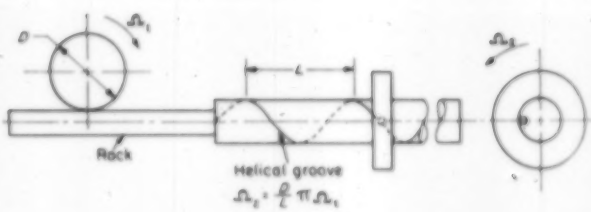
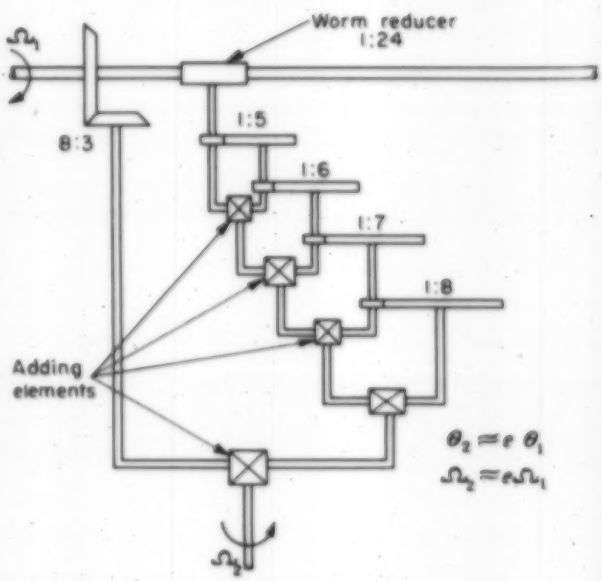


Fig. 4—Construction of a gear train with an overall speed ratio equivalent to the irrational number e. Arrangement of the gear elements is based on a numerical series expression for e



$$e = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \frac{1}{5!} + \frac{1}{6!} + \frac{1}{7!} + \frac{1}{8!} + \cdots$$

$$= \frac{8}{3} + \frac{1}{24} + \frac{1}{5!} + \frac{1}{6!} + \frac{1}{7!} + \frac{1}{8!} + \cdots$$

$$= 2.718\,28 + \cdots$$

$$\theta_1 = \frac{2\pi n}{K_t - 1} \quad \ldots\ldots (3)$$

where $n = 0, 1, 2, \ldots$ and $K_t > 1$, and also whenever

$$\theta_1 = \frac{2\pi n}{1 - K_t} \quad \ldots\ldots (4)$$

where $n = 0, 1, 2, \ldots$ and $K_t < 1$.

Thus, if K_t is irrational, the position of coincidence will never occur in integral multiples of 2π radians. In other words, with respect to a fixed co-ordinate system, *X-Y*, the position of coincidence will never repeat. On the other hand, if K_t is integral or rational, the position of coincidence will periodically repeat.

This property of nonrepetitive coincidence offers many possible applications for drives with irrational speed ratios.

Revolution Counter Relationship: If revolution counters are attached to each shaft, the ratio of the counter readings at any instant of time (each reading being rounded off to the nearest revolution) will give an approximation for K_t. As time increases, and the numbers in the counters become larger, this ratio will approach the true value of K_t as a limit. If K_t is integral or rational, the counter ratio will periodically give the exact value.

Both of the properties just discussed would hold for a mechanism in which K_t was either irrational algebraic or irrational transcendental. Thus, the general properties of a speed changer would be the same for both cases.

Drives with Irrational Speed Ratios: Examples of positive drive mechanisms which have speed ratios equal to the irrational algebraic number $\sqrt{2}$ and the transcendental number π are shown schematically in *Figs.* 2 and 3. Both types of devices have limited ranges of travel. However, there is nothing inherent in the definition of irrational numbers or in the nonrepetitive coincidence con-

PROPERTIES OF REAL NUMBERS

Complete discussions on the various categories of numbers and number theories can be found in the literature.[1,2,3] This discussion presents a brief outline of the properties of the types of numbers in the total set of real numbers.

Classes of Numbers

Numbers may be classified into three general categories:

Integers are the whole numbers, 1, 2, 3, etc., either positive or negative.

Rational numbers are numbers that can be represented by the ratio of two integers; for example, 7/8.

Irrational numbers are numbers that cannot be expressed as the ratio of two integers; for example, $\sqrt{2}$.

In addition to these main categories, two special classes of numbers are defined:

Algebraic numbers satisfy some algebraic equation of the form:

$$A_n X^n + A_{n-1} X^{n-1} + \ldots + A_1 X + A_0 = 0$$

where $n \geq 1$ and $A_n \neq 0$; n is integral and finite and all A values are integers. Algebraic numbers can be either integral, rational or irrational. All algebraic numbers of degree greater than one (i.e., $n>1$) are irrational. For example, $\sqrt{2}$ is algebraic because it satisfies the expression: $X^2 - 2 = 0$. It is also irrational since $n>1$.

Transcendental numbers are the special class of irrational numbers that do not represent the solutions of algebraic equations. The following numbers have been proven to be transcendental: the constant relating the circumference and area of a circle to its diameter, π = 3.1416 . . .; the base of the natural logarithms, e = 2.71828 . . .; and the general case, X^b, where X is any algebraic number not equal to zero or one and b is any irrational algebraic number.

Characteristics of Irrational Numbers

Rational and irrational numbers exhibit certain differences when expressed as decimals.

Rational numbers: Decimal expression is either finite, or infinite with a repeating group of digits; for example, 1/4 = 0.250 and 1/7 = 0.142857142857142 . . . . .

Irrational numbers: Decimal expression always consists of an infinite number of digits which occur in random fashion; for example, $\sqrt{2}$ = 1.41421356 . . .

Irrational numbers can always be expressed as the sum of an infinite sequence of rational numbers.

Irrational numbers can be defined by a nested sequence of intervals with rational end points which close down on the true value of the irrational number.

Algebraic irrational and transcendental irrational numbers exhibit the following important difference: Given a unit length, a straightedge and a compass, it is always possible to construct straight lines whose lengths represent rational or algebraic irrational numbers; however, it is not possible to construct lengths representing transcendental numbers.

dition which prevents the possibility of a continuous drive with an irrational speed ratio. The fact that there is an infinite number of angular positions in any *X-Y* coordinate system shows that the position of coincidence of two shafts would never of necessity have to repeat even if the rotations were continuous.

Gear Drives: There are many ways to obtain an irrational speed ratio to a close approximation. Although ordinary gear drives have rational speed ratios (usually determined by the ratios of the tooth numbers which must be integers), they can be designed for almost any desired accuracy in approximating an irrational number. For example, a pair of spur gears, one having 271,828 teeth and the other 100,000 teeth, will have a speed ratio equal to e to five decimal places. A mechanism for obtaining the same accuracy based on a series expression for e is shown in *Fig.* 4. This second method employs gears of much more reasonable size.

Friction Drives: With friction drives it is, of course, possible to obtain any desired speed ratio, but there is always an approximation involved due to the finite area of contact. The effect of this area can be seen by considering the wheel and disk friction drive shown in *Fig.* 5. Since the wheel has a finite width, different points within the area of contact touch the disk at different radii from the disk axis. Consequently, some points on the wheel within the area of contact slip over the surface of the disk. Which points slip and which points do not slip is a random phenomenon, the net result being that friction drives always involve an approximation. Despite this limitation, infinitely variable friction drives are used as the basis for integrators in differential analyzers and other analog computers.[4,5,6]

Wheel and disk integrators are a very versatile means of generating complicated functional relationships between input and output shaft positions. For computer applications, the angular positions of the shafts, rather than the velocities, are used as the variables; however, the relations between the velocities are easily determined.

In *Fig.* 5*a*, the basic components of a wheel and disk integrator are shown. *Fig* 5*c* gives a schematic

Fig. 5—Typical wheel and disk integrator systems showing: *a*, basic arrangement of system elements; *b*, schematic representation of basic arrangement; and *c*, schematic diagram of connections required to generate an exponential function. Torque amplifying devices are not shown. Basic exponentional relationships produced by the system at *c* are given in Equations 5 and 6

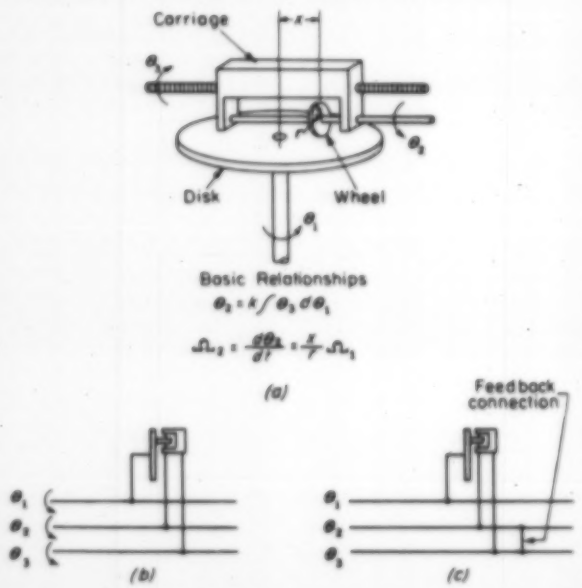


Fig. 6 — Wheel and disk integrator network for producing a speed ratio equal to the irrational number e. Torque amplifying devices are not shown

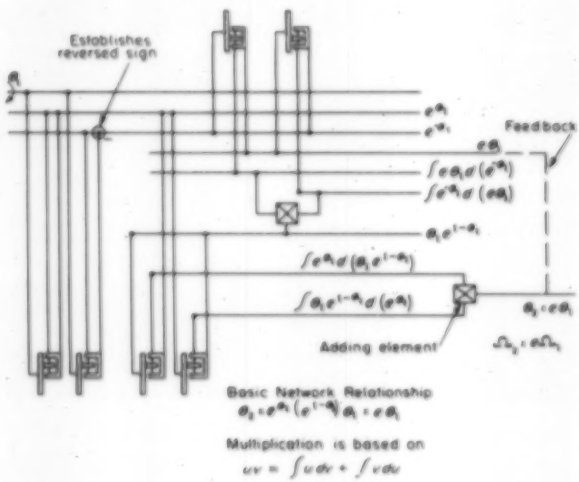


Fig. 7—Electromechanical device for obtaining speed ratios equal to algebraic irrational numbers

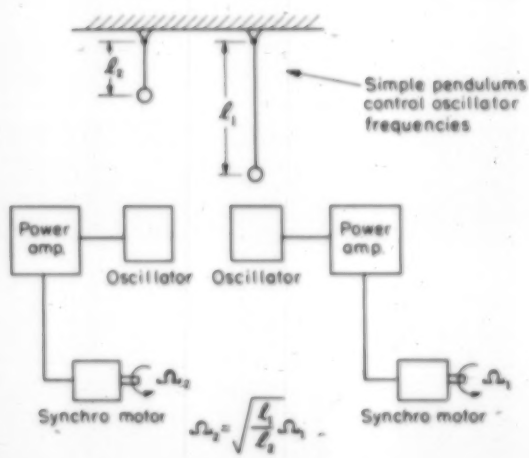


diagram of the connections required to generate the exponential function,

$$\theta_2 = e^{\theta 1} \quad \ldots\ldots (5)$$

Velocity is given by

$$\Omega_2 = e^{\theta 1}\ \Omega_1 \quad \ldots\ldots (6)$$

It can be seen that if such a device is considered as a speed changer it does not obey the relationships of Equations 1 and 2; that is, the "speed ratio" is not constant.

A schematic diagram of an integrator network for obtaining a speed ratio equal to the transcendental number *e* is shown in *Fig.* 6.

In the practical use of friction drives for computers and other fairly precise applications, the torque that can be transmitted is limited. If the torque becomes too high, a gross slippage will occur, with a large decrease in accuracy. A gross slippage is one in which all points on one surface within the area of contact move with respect to the other surface. To minimize such slippages, torque amplifiers or "angle indicators"[4] are usually used together with wheel and disk integrators. According to Bush and Caldwell,[4] the wheel and disk integrators used in the MIT differential analyzer can deliver 5 gram-centimeters torque without exceeding a slip of one part in 10,000. In the schematic diagrams shown in *Figs.* 5 and 6, the torque amplifiers do not appear.

Electromechanical Devices: If electronic elements are included in this study, many new possibilities are available for obtaining close approximations to irrational speed constants. The method shown schematically in *Fig.* 7 consists of two pendulum-controlled oscillators which lock two otherwise independent power sources together so that their angular velocities are related by a speed ratio which can be irrational algebraic. However, if discussion is restricted to the ruler and compass condition defined earlier the speed ratio cannot be made transcendental because lengths representing transcendental numbers cannot be constructed.

An important possibility with electromechanical devices is the use of a friction drive with a servo follow-up that continually adjusts the output velocity to maintain any desired speed ratio.

ACKNOWLEDGEMENT

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Properties of Thermosetting Plastics

RELATIVE properties of various grades of thermosetting plastics are given in the accompanying table. These ratings, tabulated by Dr. Norman A. Skow of the Synthane Corp., are comparative and apply only between the materials listed. Grades rated "fair" may be superior to other insulating materials in a specific application.

Machinability for all grades except nylon is rated "excellent." Nylon is rated "satisfactory" for threading, milling, drilling, turning, boring, cutting and precision machining. It is given a "good" rating for sawing, punching and shearing. Marking properties, such as etching, samping and printing, are considered "excellent" for all the listed grades.

Relative Properties of Thermosetting Laminated Plastics

Grade	General Resistance Factors					Chemical Resistance				Electrical Properties				Mechanical Strength				
	Water	Heat	Wear	Oil	Aging	Acids	Alkalis	Inorganic Salts	Organic Solvents	Dielectric Strength	Power Factor	Insulation Resistance	Arc Resistance	Tensile	Flexural	Compressive	Impact	Bonding
Paper																		
X	S	G	G	E	E	F	F	S	S	G	F	F	F	E	G	E	S	S
XP	S	G	G	E	E	F	F	F	F	G	G	F	F	E	G	G	S	S
XX	G	G	G	E	E	F	F	G	G	G	G	F	F	G	G	G	S	S
XXP	G	G	G	E	E	F	F	F	F	E	E	E	F	G	G	G	S	S
XXX	E	G	E	E	E	F	F	G	G	E	E	E	F	G	G	G	S	S
XXXP	E	E	E	E	E	F	F	F	F	E	E	E	F	G	G	S	S	S
XXXPLR	E	E	E	E	E	F	F	F	F	E	E	E	F	G	G	G	S	S
Cotton Fabric																		
CE	G	G	E	E	E	G	G	G	G	G	G	S	F	G	G	G	G	E
CM	G	G	E	E	E	G	G	G	G	G	G	S	G	G	G	G	G	G
LE	G	G	E	E	E	G	G	G	G	G	G	S	F	G	G	G	G	E
LM	G	G	E	E	E	G	G	G	G	G	G	S	G	G	G	G	G	G
Glass																		
G-5	G	E	E	E	E	G	G	G	E	G	G	G	E	E	E	E	G	G
G-7	E	E	G	E	E	G	G	G	G	E	E	G	E	E	E	E	E	S
Nylon																		
N 1	E	F	S	E	E	G	G	E	E	E	E	E	S	S	S	S	E	G

E—Excellent, G—Good, S—Satisfactory, F—Fair.

Applying Electronic Computer Controls

Recent developments in computer-controlled machine tools illustrate design factors for a new potential in machine control concepts

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DESIGN ABSTRACTS

DIGITAL computers can make a direct contribution to efficiency of small-quantity production in control of metal-cutting processes. They permit use of universal machine tools in which the setting-up time is so short that efficient automatic production of small batches and even single components can be achieved. This development has reached the stage at which prototypes are being tested, and a considerable number of machines will be put into service during 1956.

Application of computers to machine-tool control involves feeding information, in the simplest possible form, about the work to be done, into a device which will interpret this information and produce from it the necessary tool movements, at the highest possible speed, in order to machine the article from a solid block or casting to limits of accuracy required.

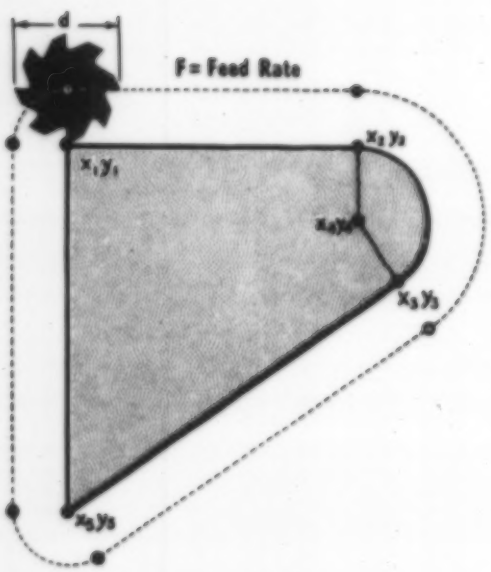

Fig. 1—Simple two-dimensional cam used as an example of computer-controlled machining, showing dimensioning and planning technique

PLANNING SHEET
x_1, y_1 = co-ordinates of datum

Type of Curve	Co-ordinates of Change Points	Co-ordinates of Pole of Curve
Straight line	x_2, y_2	
Circle	x_3, y_3	x_4, y_4
Straight line	x_5, y_5	
Straight line	x_1, y_1	

How the System Works: With modern techniques of computation and control such a process is entirely feasible. The system can be divided into four stages:

1. Transference of drawing information along with machining data to a standard planning sheet.
2. Coding of this planning sheet on to punched paper tape.
3. Production from this paper tape of a recorded magnetic tape by means of a digital computer.
4. Use of this magnetic tape to control the machining operation.

The article is designed and a drawing or sketch made in the usual manner, the only departure from normal practice being in the precise method of dimensioning, where all dimensions are given from a datum and include the co-ordinates of all points of change, i.e., where a straight line joins a curve and so on. Thus, the designer has considerably greater scope in the selection of contours than with normal machining methods.

Planning: The drawing of a part to be machined goes to a planning engineer whose function is to know the capabilities of the machine and how the article should be machined. He inserts dimensional information from the drawing in correct sequence in a standardized planning sheet, interspersing drawing data with information regarding cutter radius which he has selected, along with feed rate, rotational speed and other machining data. In order that the system should have maximum possible utility and give greatest freedom from human error, information required is kept down to its simplest possible form, consisting basically of co-ordinates of points of change of the surface of the work and a specification of the curve between pairs of co-ordinates.

Thus, as a hypothetical example, *Fig.* 1 shows a simple two-dimensional cam, the planning sheet for which would be as indicated.

No co-ordinate information need be given between points which can be specified by an equation or parameters of a curve, such as the center and radius of a circle. This example shows a contour in two dimensions, but there is of course no difficulty in extending this technique to three dimensions.

Paper Tape: The planning sheet goes to a typist who transfers the data to the form of punched tape by means of a teleprinter.

Computer: The short length of punched paper tape now contains the minimum basic amount of information required to produce the component, but in order that a component can be produced from it, this information has to be extended and the gaps between co-ordinate points filled in. This is done by the digital computer which accepts the basic information and, controlled by the equation of the curves, calculates continuously the required path of the center of the cutting tool in x, y and z co-ordinates. The output in each co-ordinate is in the form of a train of pulses, each pulse corresponding to a very small unit of movement, usually 0.0001-inch. Thus, total number of pulses in each channel determines the distance moved in that co-ordinate, and pulse rate determines the speed of movement or feed rate. These pulses are synchronized in the x, y and z channels in such a manner that a tool controlled by them follows a path corresponding to the calculated track within 0.0001-inch. These pulses are recorded on three separate channels on magnetic tape and simultaneously, on a fourth channel, control information, pertaining to functions of the machine other than slide movements, is recorded.

Types of curves which may be covered are limited only by complexity of the computer, but for normal engineering uses it is expected that a computer with built-in programs, which will contour any curve which may be specified by a second-degree equation, including circles, ellipses, parabolas and hyperbolas, will be satisfactory. More complex shapes which occur only rarely can be approximated with sufficient accuracy by a combination of such curves. Surfaces which can be specified as a series of ordinates are best produced by means of a computer which can utilize ordinates and produce a smooth curve through them.

A modern digital computer can handle information at a much higher rate than the highest feed rate used in practice. Advantage is taken of this fact to record pulses on magnetic tape moving at ten times normal play-back speed. This is of considerable importance as it means that one computer can record tapes for a large number of machines. Its paper tape input can be prepared by a number of planners without occupying computer time, and the number of machines controlled depends only on computer speed and average duplication rate.

With a ratio of computer speed to machining speed of ten and an average duplication rate of five, varying from unity for single prototypes and tools to say ten or twenty for component parts, a single computer could supply fifty machines with recorded tapes. In addition, a tape link allows the amount of electronic equipment to be reduced to a minimum.

Various checks are included in the system in order that errors may be discovered before any machining is done. The data, up to the point where it emerges as a coded paper tape, is checked by techniques normally used in punched-card accounting systems, which involve basically duplicating the work and comparing the results. In addition a further check of the whole system right up to the magnetic tape is possible if the work is programed in closed loops, that is, the tool is arranged to touch its previous path several times during the operation. This is always possible even though the tool may be lifted away from the work for part of the time where no cut is required. At the point where the loop should close, a marker pulse is recorded on the magnetic tape and the pulses in the x, y and z channels counted

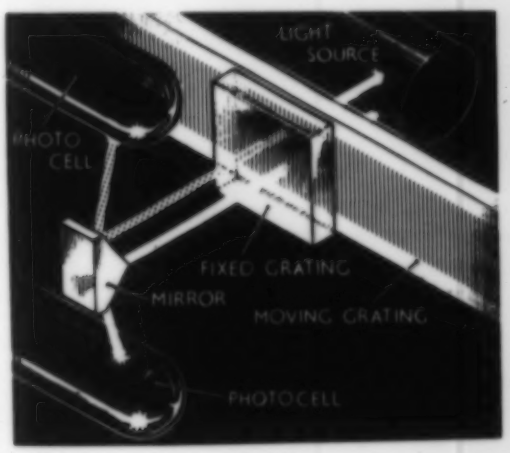

Fig. 2—Diagrammatic illustration of the Ferranti optical-grating measuring system

immediately after recording in order to see that they summate to zero at these points. If a tape passes this test it is reasonably certain that it is correct and when put on the machine will produce accurate work.

Controlled Machine: A digital computer can produce control information of the type just outlined to any desired degree of accuracy, but this is useless unless the measurement and control system of the machine slide has a similar degree of accuracy.

No great reliance can be placed on the use of a leadscrew as a method of measurement, although this is normally the only measuring agent fitted to machines. Problems of backlash and the compressibility of the oil film render such a system useless where machining must be done to close tolerance by dead reckoning.

The ideal method would be to measure the actual surface of the work as it was being cut. This is technically feasible for turned articles where the surface is available at a different position from the cutting position a very short time after it is cut, but it is not possible to do this in milling because the work is obscured by the cutter. The best that can be achieved is to measure the movement of the surface of the table on which the work is fixed, relative to the main body of the machine. With this method the machine and tool deflection will cause an error, which can be reduced to a suitably low value by designing the machine correctly. In general the principle which has been adopted is that the measurement system should be rather better than the accuracy to which the machine can normally work; thus any machine, taken as designed, is used to its maximum capability.

Optical-Grating Measuring System: Various mechanical methods of measurement which produce a digital electrical output suitable for automatic control are possible. Most are based on the rack and pinion principle and are troublesome where high accuracies have to be achieved, because of factors such as the presence of dust, variability of oil film thickness, tooth ripple and so on.

A method of measurement with none of these disadvantages has been devised utilizing an optical grating with a specified number of lines per inch. This method has the advantage that the accuracy is unaffected by wear and can be made as high as desired. For instance, with a grating of 25,000 lines per inch it would be possible to discriminate between a few millionths of an inch, provided of course that attention was paid to all the other factors which affect such fine measurement, such as temperature, vibration and slide design. By the use of gratings with 5,000 lines per inch it is a simple matter to move a slide consistently to an accuracy of 0.0001-inch, which is sufficient for all normal engineering processes and is better than the inherent cutting accuracy of most machines.

Method of utilizing gratings for measurement is shown in *Fig.* 2. A suitable length of grating is attached to the machine table, and a short length of the same grating attached to the other section of the slide, so that one grating traverses the other with the two surfaces almost in contact. If a beam of parallel light is projected through the pair of gratings and they are suitably aligned, the Moire fringe pattern produced will modulate the light transmission when there is relative movement. One complete cycle of variation of intensity will occur for a movement equal to the pitch of the grating. By arranging two photocells so that the phase of this light variation is different in each, a two-phase electrical system can be formed, the total number of cycles of which represent the distance

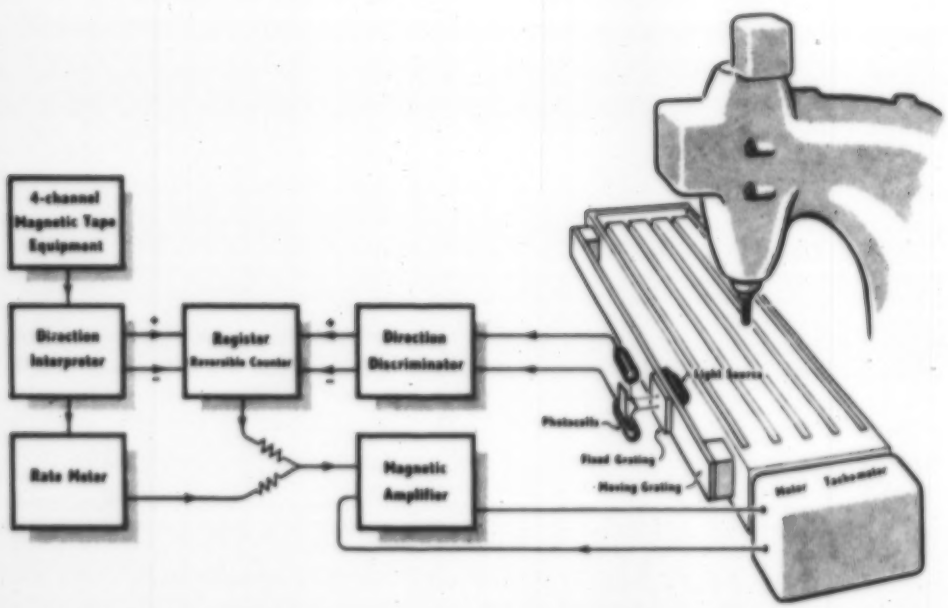

Fig. 3—Diagram of digital machine - control servomechanism

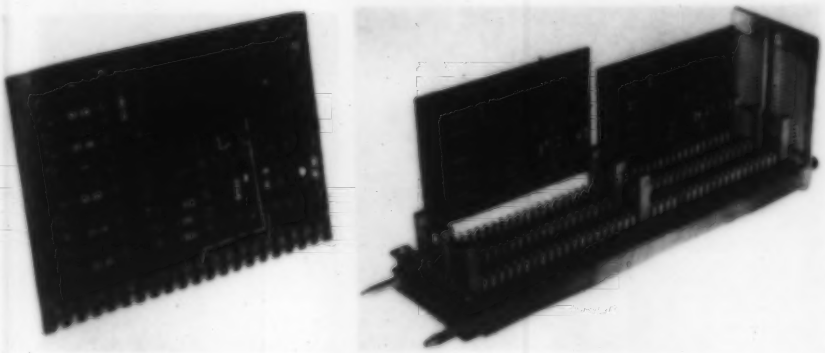

Fig. 4—Plug-in type of construction, well suited to automatic control systems. Circuit card with automatically soldered connections, left, is plugged into tray, right, which will accommodate six cards

moved. Frequency represents velocity, and direction of phase rotation reveals direction of movement of the slide. It is a simple matter to obtain, from this system, two or more discrete electrical pulses per grating line.

Digital Servomechanism: A block diagram outlining the servomechanism which translates the pulse trains from the magnetic control tape reader into accurate slide movements is illustrated in *Fig.* 3. Considering one channel, the control pulses are fed to a direction interpreter, and according to the direction they represent, are passed to a register. This is a reversible counter with a small storage capacity, producing an electrical output proportional to the magnitude and direction of its contents. The control pulse train is also fed to a "ratemeter" which produces an electrical output proportional to its repetition frequency and direction. These combined outputs actuate a high-performance secondary servomechanism to drive the table. Positional feedback from the table is obtained from a grating and direction discriminator, and the pulses from this are used to cancel the command pulses in the register. The system is so arranged that the error between the command pulses and the positional feedback from the table does not exceed one pulse, giving a maximum error in slide position of half a grating line.

In order to avoid an accidental overload of the servomechanism which might produce an error, the computer is arranged to limit the maximum rate of change of command information to that which may be handled safely.

Reliability: Automatic control systems of this type must be engineered so that they are highly reliable and the occurrence of faults very infrequent. Circuit elements must be chosen which are known to be reliable. In the system described, the most frequently occurring elements are carbon resistors and germanium diodes, and circuits have been designed round these elements in such a manner that the possibility of failure is minimized. In industrial equipment of this degree of complexity it is important to avoid circuits which have critical operating conditions or components. Use of automatic self-checking procedures is worthwhile, and it is beneficial to carry out a marginal testing procedure each day by reducing supply voltages while a standard checking program is being handled. Any circuit elements on the verge of failure are likely to be shown up by this method. In spite of this, faults may occasionally occur, and it is essential that they can be located and replaced rapidly. The type of plug-in construction shown in *Fig.* 4 is particularly suited to these requirements.

It is of course essential if a fault occurs in the control section of the equipment that the machine should cease to cut immediately, in order to avoid ruining the work. This can be done by having signals from the registers, which reveal all deviations between the demanded position and the actual position of the slides, shut the machine down if the deviation exceeds a certain pre-determined limit. This, in combination with two anti-coincidence counters covering the channels from the tape to the register and from the grating to the register, can give a complete check on the behavior of the machine.

Errors Due to Machine Inaccuracies: Errors caused by imperfections of the machine tool are mainly due to slide inaccuracies and play, lack of rigidity, backlash in the drive system and friction. Under normal running conditions, the grating measuring system will provide accurate positional information which will enable the servomechanism to correct errors due to backlash and slide inaccuracies.

To assist servomechanisms in dealing with backlash, the computer can be arranged, when a reversal of the slide is required, to set in one pulse in the reverse direction automatically and then wait for a fraction of a second to give the servomechanism time to cancel this pulse before proceeding with the rest of the train.

Design of machine tools has not changed radically for many years and is, in general, unsuitable for very accurate automatic control. Kinematic design is almost unknown, and as a result machine slides are difficult and expensive to make and even more difficult to maintain in a good state of accuracy. The efficiency of a slide and drive system rarely exceeds 15 to 20 per cent, and hence a relatively high power is required to drive it. In the past this was of little consequence as it merely necessitated a large motor which was not proportionately expensive. In a controlled machine, however, this power has to be provided by a servomechanism, and is very much more expensive per horsepower than before. In addition, servomechanism performance inherent-

ly drops as the size is increased, so inefficiency is dearly bought.

The use of kinematic elements such as recirculating-ball nut and leadscrew assemblies and bushings, spring-loaded to the level of the maximum loads to be encountered, can be made to give high efficiency and complete freedom from maintenance troubles combined with a high degree of rigidity and lack of play and backlash. Replacement of the conventional leadscrews of the prototype computer-controlled milling machine by recirculating-ball nut pairs with special leadscrews, preloaded to the maximum table force of 500 lb, has been markedly successful. Transmission efficiency has been increased from 20 per cent to 80 per cent, while backlash has been reduced to less than 0.0001-inch. This performance will not be subject to deterioration due to wear.

Fig. 5 — Computer-controlled drilling machine using computer for positioning rather than continuous motion

Positioning Machines: In addition to the application just described, in which the machine table is under the control of a magnetic tape at every instant in time, there is another important use of the grating measuring system in machines in which the table merely requires to be positioned. Jigborers, drilling machines, turret and automatic lathes are machines of this type. Such applications are very much simpler than the one just described, as it is necessary only to set up a number, corresponding to the dimension, on an electronic counter and to cancel this number by the count from the grating measuring system. The setting-up can be done by hand or automatically by means of punched card or paper tape. Great speed and accuracy are obtainable by this means, particularly when a pattern of holes has to be drilled on a repetitive basis as with heat-exchanger plates, gear plates, etc. *Fig.* 5 shows an example of a controlled drilling machine.

From a paper entitled "Computer-Controlled Machine Tools" presented at a conference given by Ferranti Ltd. at Margate, England, June, 1955.

Solving Engineering Problems

How organized thinking habits can evolve into effective group creativity

By C. F. Hix and D. L. Purdy

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THE notion that only a few extraordinary individuals possess creative ability still lingers in contemporary thought. Some believe that an unknown power caused such men as da Vinci, Michelangelo, Bacon, Faraday, and Edison to produce their ideas rapidly and fluently. The feeling that creativity is necessary only to inventors, researchers and designers minimizes its importance in such fields as engineering analysis. Although creativity is subject to illusive interpretations, in the past 30 years creativity has been recognized as an asset to everyone in all fields of endeavor.

Essentially, all work requiring conscious thought consists of a continuous series of problems or unanswered questions. Men thought to be creative in the past recognized unusual problems and originally and uniquely solved them. However, anyone who solves any problem is being creative to some degree, if he is unaware of the existing solution.

Study of creative-problem solutions reveals that generally problems are solved in a logical, chronological sequence. This can be called the creative approach. Everyone has a certain innate creative ability that can be developed by teach-

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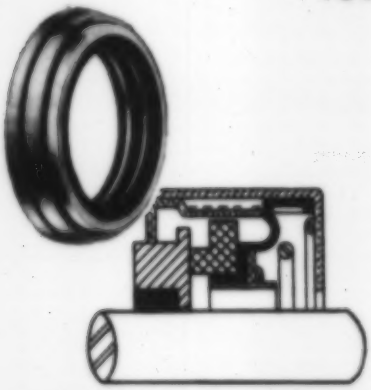
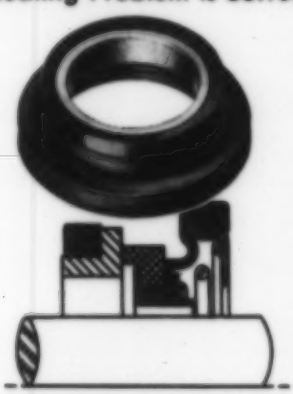
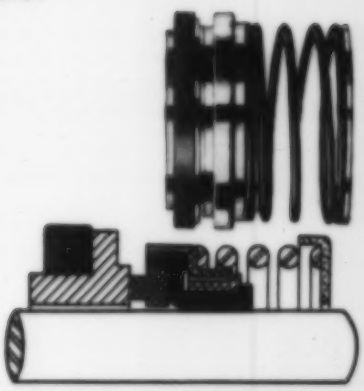


STYLE GU — A packaged sealing unit containing both rotating and stationary seal faces enclosed in metal housing. Important applications in machine tools and power transmission equipment. Stock sizes for shafts .250 through 4.000.

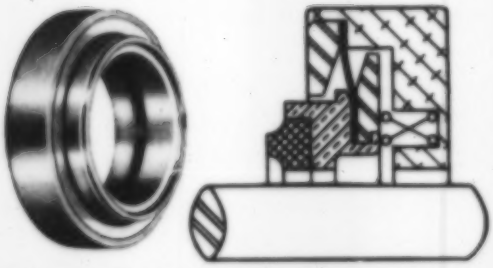


STYLE SGU—A factory-assembled unit-type seal for the small budget user. Widely used in appliance field. Stock sizes for shafts .250 through 1.000.

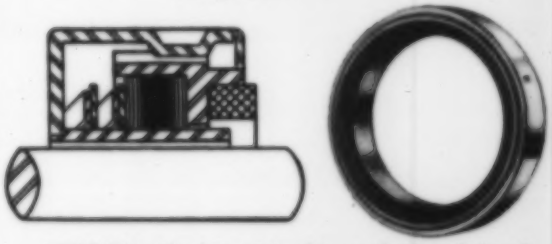


ROTO-FLEX — Rugged flexibility. Only 3 parts. Single or double units. Many applications in pumps and compressors. Stock sizes for shafts .250 through 4.000.

STYLE RFO—A specially designed Roto-flex seal, for installation outside the stuffing box. Stock sizes for shafts .250 through 4.000.



STYLE DPC — A high-speed, carbon-faced seal, for use where lubrication is poor or where shaft RPM and resulting friction are high. Ideal in many machine tool applications. Stock sizes for shafts .250 through 4.000.



STYLE HH—Absolute minimal space (both radial and axial) under extreme conditions of temperature, pressure and seal face surface speed. Features pressure balance when fluid pressure is applied internally or externally. Of particular importance to the aircraft industry. Stock sizes for shafts .250 through 4.000.

These are only a few of the countless sealing problems now being solved by

GITS SHAFT SEALS

Write for detailed data on any of these standardized stock Gits Shaft Seals.

GITS BROS. MFG. CO.

1868 A S. KILBOURN AVE. CHICAGO 23, ILL.

Specialists In Lubricating Devices And Shaft Seals For Almost Half A Century

ing a procedural problem approach together with useful techniques for cultivating the imagination. The problem approach not only increases a man's ability to arrive at a unique and original solution but also clarifies his thinking when faced with an unsolved problem. Regardless of where the problem lies—marketing, engineering, product development, research, manufacturing, or human relations—this approach is useful.

A Problem Approach: An engineer's responsibility lies not only in accumulating unique ideas but also in organizing and controlling his work in an orderly and efficient manner. Many engineers tend to accept the first thought that comes to mind rather than to carefully define the problem and search for a variety of solutions.

The Creative Engineering Program at General Electric has evolved a system that assists in all problem-solving situations, *Fig.* 1. When the program began in 1936, two areas in every question were obvious: the problem and the solution. This developed into the four-step approach, publicized from 1950 to 1953. When the four-step approach was applied to the more technical type of problem, certain areas proved to be weak or lacking, and so a more refined type of approach evolved.

If the experienced engineer analyzes his own problem-solving procedure, he will find that he automatically follows these steps. However, few of us carefully analyze the segments of our thinking, although to do so would greatly improve our own attack on a problem. Often we neglect or are weak in certain areas of our personal approach.

The problem approach can be applied equally well to problems in every field—from mathematics to appearance design. For its application to a typical problem involving creative thinking by a group of engineers, see *Table* 1. All the steps of an overall approach to a lengthy problem constitute a succession of smaller problems—also solved by the problem approach.

By following an organized approach in any problem, an engineer or group of engineers not only eliminates wasted time spent in disorganized thoughts but also plans and schedules time efficiently. Steps of the problem approach serve as concrete chronological objectives.

From "Creativity Can Be Developed" in General Electric Review, *May,* 1955.

Table 1—Creative Approach to a Typical Problem Solution

Step 1—Recognize the Need

Because thrust in a jet engine is a function of mass fuel flow, the Air Force needed a device to measure the mass rate of flow to the engine. At that time the meters used were unsuitable, because compensation had to be made for errors caused by density and viscosity changes of the fluids.

Step 2—Define the Problem

General Electric and the Air Force jointly prepared such specifications as:

Flow measurement on a mass basis independent of fluid density and viscosity.
Low pressure-loss.
Small size and weight.
Linear response.
High accuracy.
No temperature error.
No vibration error.
Long life (2000 hours minimum).
Pass salt-spray test.
Be independent of fuel used.

Step 3—Search for Methods

A few of the numerous ideas considered included:

Coriolis principle.
Variable area nozzle.
Flettner principle.
Restrained propeller.
Rotating propeller.
Angular change of momentum.

Step 4—Evaluate Ideas

The practical and theoretical soundness of these principles was carefully investigated. Mathematical derivations helped to calculate required size, pressure loss, and relationships of output signal. A sample based on the Coriolis principle proved practical, although rather large.

Step 5—Select the Best Proposal

The ideas developed to the point of practicality in Step 4 were compared with each other to decide on the one most nearly meeting the specifications. The small-sized angular momentum change device appeared most promising and was selected for its low pressure-drop and its promise to give a linear output with input mass rate of flow.

Step 6—Preliminary Design

A carefully constructed prototype sample based on mathematical calculations arrived at in Step 4 was tested, modified slightly, and retested. It completely fulfilled the rigid Air Force specifications.

Step 7—Demonstrate with a Sample

The prototype sample, proved to the engineers' satisfaction, was demonstrated to the Air Force and accepted for production design and manufacture.

Step 8—Follow Through

Although the engineers had completed their job of fundamental theory and design, they followed the design through its manufacturing and production stages—probably a never-ending phase.

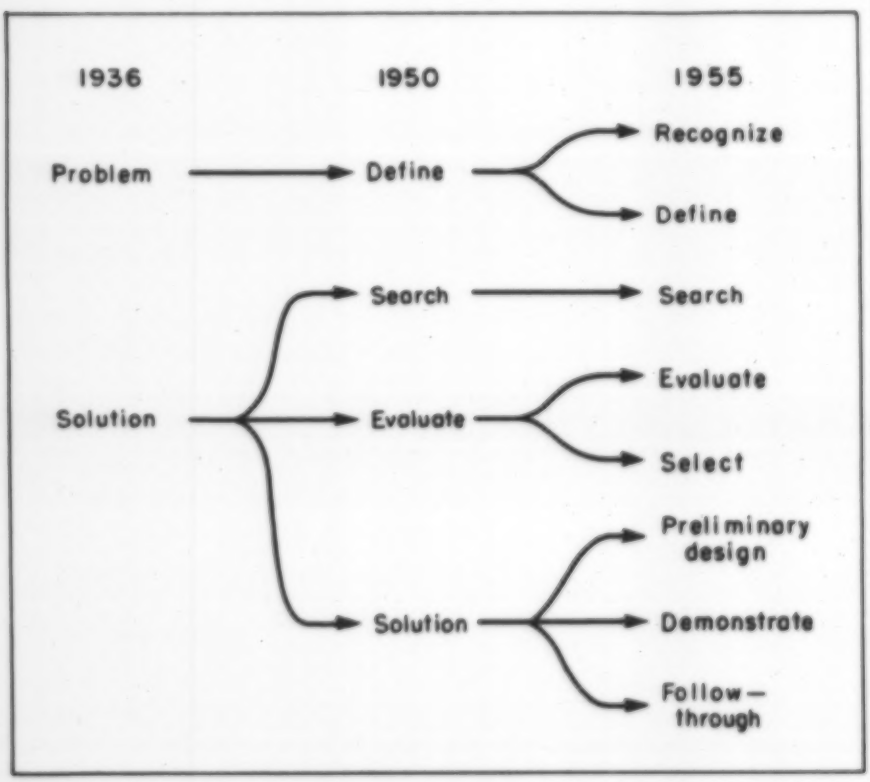


Fig. 1—Evolution of design problem approach

HOWELL MOTOR BRIEFS

Quick facts for those who apply and specify electric motors

New Stator Design is a Motor Life Saver!

One sure way to save years of motor life is to provide a better means of removing excess internal heat. That's what has been accomplished by the new stator lamination design developed for the Howell Series 100 motors.

Instead of the conventional smooth outer surface, this stator has wide ventilation slots in its circumference. With the dividing "fins" fitted against the motor frame, air passages are created that put 50% more stator heat transfer surface in direct contact with the flow of fan-driven air.

Copper-clad rotors shed heat faster, too

Rotor slot bars and end discs are a bonus feature of all Howell motors. Note below right the much greater thermal conductivity of copper, as compared to aluminum, the metal in common use for cast rotors today.

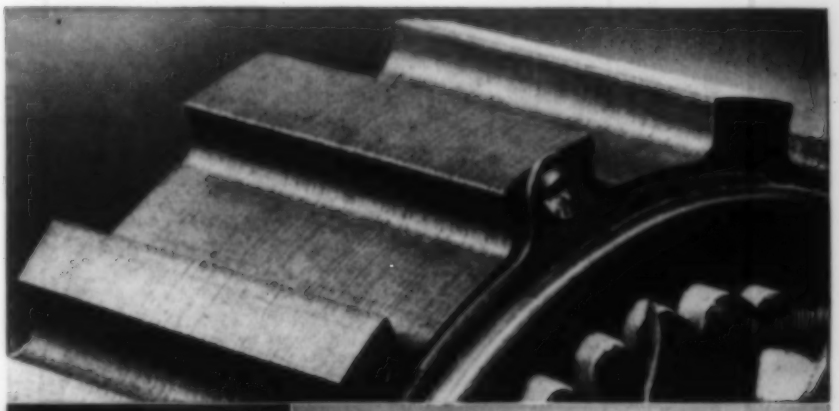
Significantly better heat dissipation is one of the reasons why Howell engineers, in designing for the new frame sizes, came up with such an outstanding group of motors in the new Series 100. They are not only smaller and lighter, they're cooler running than their horsepower equivalents in the old frame sizes.

Why not go modern in motors?

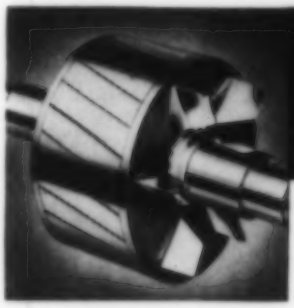
Fact is, you really can't afford to pass up the Howell Series 100 Rerated motors without investigating their potentials for your machine modernization programs. They give you space savings, weight savings and new, sleek good looks—along with construction features like these: Mylar-lined slot insulation, fully protected cartridge type bearings, resilient steel frames and mounting feet, and permanently position-identified leads. These are a few of the gains; let us tell you about the rest.

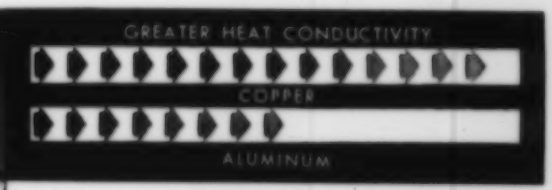
Series 100 enclosures: totally enclosed fan cooled, open drip-proof, splash-proof and weather protected, sanitary, explosion-proof, and totally enclosed non-ventilated.

Write for new Bulletin N-100-R



Illustrations above and at right show the first real advancement in motor ventilation in years—made possible by the slotted stator design of the new Howell Series 100 motors.





The thermal conductivity (K factor) of copper is 91% greater than that of aluminum. Copper's electrical resistivity is 35% less. Two good reasons for Howell's use of copper-clad rotors in Howell Series 100 motors of *all* horsepowers.

HOWELL Red Band MOTORS

HOWELL MOTORS

HOWELL ELECTRIC MOTORS COMPANY, HOWELL, MICHIGAN

PRECISION-BUILT MOTORS FOR INDUSTRY SINCE 1915

TORRINGTON

NB SERIES NEEDLE BEARINGS

For Oscillating Motion or Heavy Rolling Loads

Torrington NB Series Needle Bearings employ the same needle roller principle as the famous DC Type Bearing.

They are available in the five types illustrated, all being of nonseparable construction and designed for periodic relubrication. Outer and inner races are of high carbon, chrome steel, hardened and precision ground.

Like the DC Type, the compact design of NB Series Needle Bearings permits saving in size and weight of surrounding parts.

Torrington NB Series Needle Bearings have been used extensively in the aircraft industry and for ordnance work where their extremely high static capacity and anti-friction characteristics enable them to withstand heavy impact loads.

Designs can be modified to meet industrial applications involving rotating motion.

Type NBC—oscillating motion only. Designed specifically for applications in which the OD is supported by a housing and the washers are backed up by clamping surfaces.

Types NBE and NBK—oscillating motion only. Self-aligning. Designed for applications where it is difficult to obtain alignment during assembly or where deflections make a self-aligning bearing desirable.

Types NBF and NBL—heavy rolling loads. Designed for use as rollers under heavy loads at slow speeds.

See our new Needle Bearing Catalog in the 1955 Sweet's Product Design File—or write direct for Catalog No. 55.

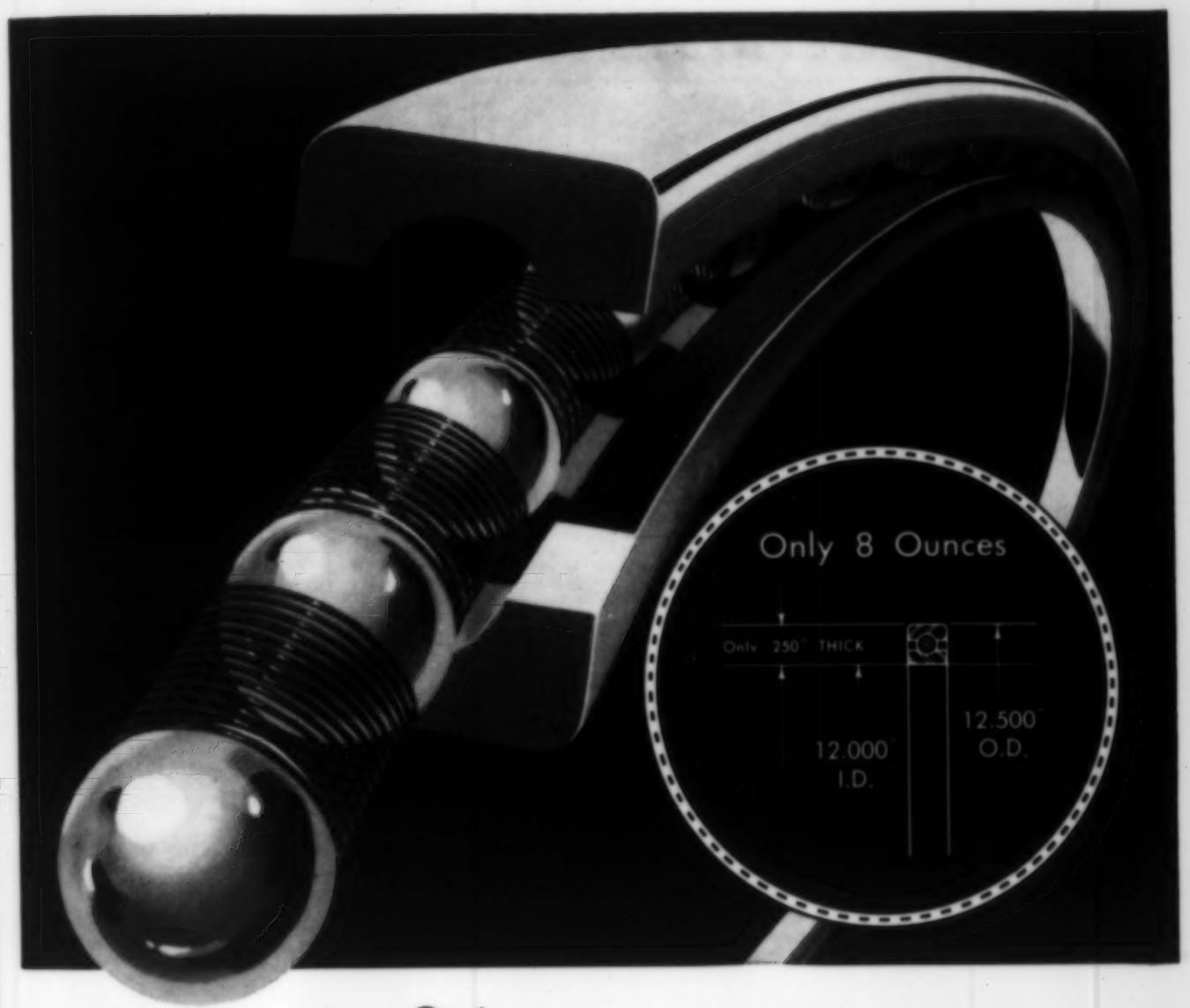
THE TORRINGTON COMPANY

Torrington, Conn. **South Bend 21, Ind.**

District offices and distributors in principal cities of United States and Canada

TORRINGTON NEEDLE BEARINGS

Needle • Spherical Roller • Tapered Roller • Cylindrical Roller Ball • Needle Rollers



Reali-Slim... by Kaydon
world's thinnest radial ball bearing

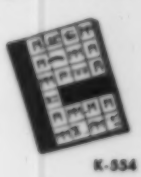
HERE'S a typical example of Kaydon's *Reali-Slim* unique radial ball bearing that's finding wide application in practically every industry. *Reali-Slim* are the world's finest thin-section bearings and proportionately are thinner than a wedding ring. The bearing illustrated here is 12.000" I.D., 12.500" O.D., .250" thick — weighs less than 8 ounces. Designed for minimum weight and space limitations, it has a static load capacity of 5,520 lbs. and 894 lbs. at 100 rpm.

If you're looking for *Reali-Slim*, lightweight, radial ball or roller bearings, look at Kaydon's *Reali-Slim* line. Besides hundreds of standard *Reali-Slim* designs, there's a wide variety of special races, seals and separators to meet special bearing problems. What's more Kaydon is able to produce these *Reali-Slim*, high-precision bearings because Kaydon specializes in the unusual. In addition, Kaydon bearing engineers are prepared to give you valuable help with technical bearing application problems.

For complete data on *Reali-Slim* bearings for standard or special applications, ask for engineering Catalog No. 54 RS.

***Reali-Slim* Ball Bearings** — in Conrad, angular contact, 4-point contact and other types are available in seven standard cross sections from .250" to 1" and in bore diameters from 4" to 40".

***Reali-Slim* Roller Bearings** — in radial or taper roller types are available in cross sections from 5/16" and in bore diameters from 5" to 40".



K-554

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

All types of ball and roller bearings — 4" bore to 120" outside diameter . . .

Taper Roller • Roller Thrust • Roller Radial • Bi-Angular Roller • Spherical Roller • Ball Radial • Ball Thrust Bearings

Helpful Literature

(*Continued from page 248*)

two-stage mechanical booster pumps in sizes from ¼ hp with 2 cfm to 40-hp 780-cfm displacement units are covered. Photos show installation in impregnation equipment, electric furnaces, vacuum coaters, oil reclamation systems, spin pits, packaging machines, air conditioning units, power plant condensers and rotary exhaust tables.

36. Vertical Hollow Shaft Motors

A. O. Smith—Construction of vertical hollow shaft motors for vertical turbine pumps is described in detail in 8-page brochure identified as section 6, page 815. Featured components of motors are covered separately. Oil-lubricated units are offered in frames 326 and larger, while grease-lubricated motors have 254 and smaller frame sizes.

37. Drafting Room Furniture

Stacor Equipment Co.—20-page catalog 553 demonstrates the interrelated working efficiency of Lifetime steel line of drafting room furniture and drawing, tracing and x-ray equipment. Booklet features filing cabinets, 4-post drafting tables and drawing tables, 4-post tracing tables and portable tracing boards, taborets, x-ray filing cabinets, tables and steel tripod easels.

38. Sealed Panel Instruments

Weston Electrical Instrument Corp.—Direct current, rectifier type alternating current, thermo, and movable iron type ac ruggedized and sealed panel instruments in 1½, 2½, 3½ and 4½-in. sizes are subject of catalog A-38-B. Both military and commercial types are offered. These instruments in sizes 2½, 3½ and 4½ in. have external zero corrector, and all can be readily opened and resealed using a screwdriver.

39. Variable Speed Drive

Cleveland Worm & Gear Co.—Line of type K Speed Variators with constant horsepower input ratings has been supplemented with addition of nine type KL models for constant torque applications. 8-page bulletin K-200 provides description, ratings, dimensions and other data on all models which now include 18 standard sizes.

40. Oscillogram Processor

Consolidated Engineering Corp.—Available literature includes 4-page bulletin 1537C on the type 23-109 processor for oscillograms; data sheet CEC-1517 C on a compact system for measurement of vibrational amplitudes in 8 to 800 cps range; and data sheet CEC-1556 which describes pickups for applications requiring measurement of low differential pressures.

41. Combination Tube Fittings

Flodar Corp.—Combination self-flaring fittings for ¼ to 2 in. OD tubing are described in 4-page catalog BA 555. Fittings eliminate flaring, threading, soldering or welding and allow unrestricted flow of fluid through tubing at the joint.

42. Relief Valves

Fluid Controls, Inc.—To assist designers of hydraulic systems in selecting the most practical relief valve for any application, 4-page guide 1.0 outlines advantages and limitations of four basic valves and gives typical applications for each.

43. Vibration Isolators

Lord Mfg. Co.—Complete data on Temproof mountings for vibration isolation is provided in 6-page technical folder 700. Used on airborne electronic equipment as well as for stationary industrial equipment, mountings withstand temperatures from —80 to 250° F.

44. Magnetic Ingot Iron

Armco Steel Corp.—High permeability and good demagnetization qualities make Armco magnetic ingot iron suitable for such direct current applications as generator frames and yokes and relay cores. Illustrated 20-page brochure 7954 relates its applications, analysis, properties and much other technical data. Information on machining, welding and drawing is included.

45. Panel Instruments

Phaostron Co.—Custom panel instruments which meet rigid performance requirements of MIL-M-6A are covered in descriptive bulletin P4C-1. Instruments feature antimagnetic shielding, insulated zero adjustments and measure 4½ in.

46. Electric Motors

Peerless Electric Co.—Line of ¼ to 30-hp single-phase, polyphase and direct current motors now available are described and specified in 8-page bulletin SDA-155. Piece provides information on selection of motors, enclosures, special mountings and modifications, and fractional and integral horsepower frame sizes.

47. Roller Chain Sprockets

Cullman Wheel Co.—16-page illustrated catalog 184 contains descriptions, technical data, prices, mounting and dismounting instructions for line of Grip-Master sprockets. Hub, fixed bore and plate types are included. Also covered are roller chain flexible couplings and standard single-strand chain.

48. Bushings & Dowel Pins

Acme Industrial Co.—Extensive line of drill jig bushings, plus dowel pins and liner and leader pins and bushings are subject of 24-page catalog No. 10. Plain press fit, shouldered press fit, removable slip, replaceable stationary and liners are types of bushings covered. Range, drill size and all dimensions are given. Dowel pins are made in six classes.

49. Eddy Current Brakes

Eaton Mfg. Co., Dynamatic Div. — Wide range of sizes and designs of eddy current brakes and associated controls for varied requirements are covered in 12-page illustrated bulletin BR1. As there is no mechanical contact between rotor and stationary field, operation is smooth and shock-free. Air and liquid-cooled types are described and applications, capacities and curves given.

50. Stepping & Key Switches, Relays

Automatic Electric Sales Corp.—Functions, specifications and other data on stepping switches, relays and key switches are found in this illustrated 4-page catalog 1843. Guide aids in selection of seven relay types.

51. Solenoid Valves

A-P Controls Corp.—Line of solenoid valves for use with liquids, gases or refrigerants is subject of 6-page illustrated bulletin RS141, section C. They can be used to start and stop operations, in mixing and blending, metering or measuring, and controlling pressure differential, pressure, temperature and flow. Selection data, features, ratings, coil frequencies, liquid capacities and typical applications are listed.

52. Magnesium Fabricating Facilities

Brooks & Perkins, Inc.—Facilities and services for fabricating, assembling and finishing magnesium and titanium are covered in 8-page pictorial folder. Also shown are commercial products produced.

53. Solenoid

Dormeyer Industries — Offered with solder terminals, but available with flexible leads, this small and lightweight solenoid is rated for constant and intermittent duty on 115 v, 60 cycles ac. It is described and its dimensions and performance data given in illustrated data sheet.

54. Small Motor Switches

Cutler-Hammer Inc. — Toggle, rotary and pushbutton switches for a wide variety of applications are described in illustrated 16-page booklet EC-79. Selection chart covers quick make, quick break and slow make, and slow break types. Electrical ratings, type or terminals, sizes, dimensions and prices are given for light, standard, heavy and extra heavy duty models.

55. Industrial Engines

Chrysler Marine & Industrial Engine Corp.—Model 32 and 33 gasoline industrial engines, available with chain or gear drive front ends, are subject of 6-page illustrated folder. The 6-cylinder units have 265 cu in. displacement and are rated at 28.35 hp. Performance curves, optional mountings and other data are included.

56. Dry Fluid Drive

Dodge Mfg. Corp.—Illustrations, cross section engineering drawings and technical data for the Flexidyne dry fluid drive are found in 12-page bulletin A-640. It shows two methods of selection with easy-to-use selection charts. Covered are the Flexidyne drive with Taper-Lock sheave and Flexidyne coupling with Taper-Lock bushing.

57. Temperature Control Systems

Barber-Colman Co., Wheelco Instruments Div.—Aid in selection of sensing elements and their correct use in the application of automatic control to industrial processes is provided by this 8-page bulletin "Temperature Control Systems." Explanation of various types of systems, ranging from two-position "on-off" to proportional position with automatic reset, is included.

58. Flexible Metal Hose

Flexonics Corp.—Rex-Weld corrugated metal hose, Rex-Tube convoluted hose, Rex-Flex stainless steel flexible metal hose and numerous special purpose assemblies are covered in 12-page illustrated catalog 147. Coupling data are also included, along with a four-step guide for selection of proper hose type.

59. Speed Reducers

Foote Bros. Gear & Machine Corp.—Line-O-Power speed reducers with capacities ranging from fraction to 150 hp are subject of comprehensive 40-page illustrated engineering manual LP No. 3. All feature simplicity, compactness and durability of components. Engineering data and specifications for all models are included.

60. Industrial Enclosed Switches

Minneapolis-Honeywell Regulator Co., Micro Switch Div.—General purpose, sealed, heavy duty limit, hand operated and maintained-contact switches are among types of enclosed industrial switches described in illustrated 28-page catalog No. 83. Use is on either alternating or direct current. Variety of actuator designs, contact arrangements and electrical ratings are offered.

61. Heavy Duty Air Cylinders

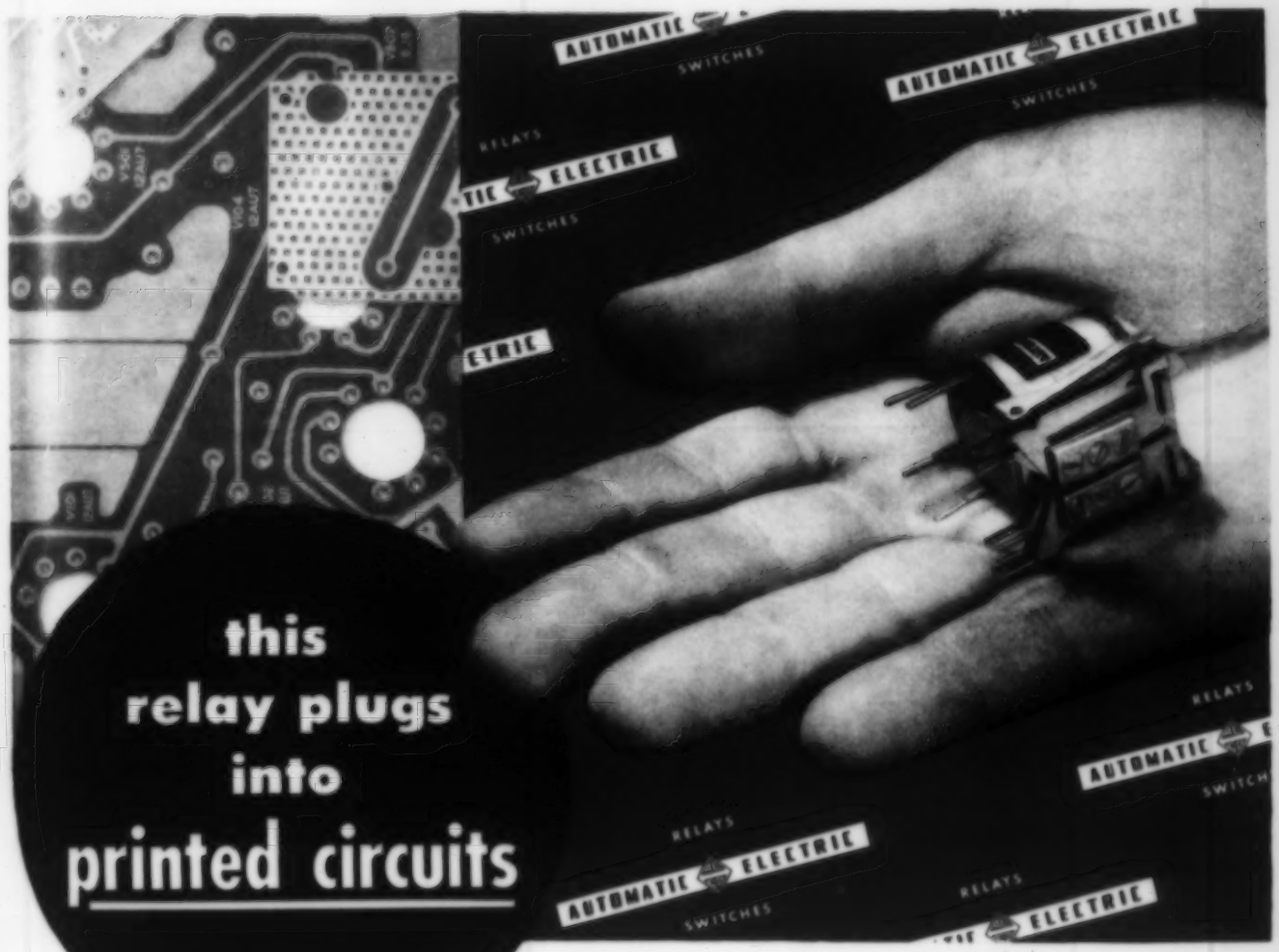
Miller Fluid Power Co.—Design, construction, engineering, mounting and dimensional data on 200-psi heavy duty air cylinders are contained in 8-page bulletin A-105K. They have bores from 1½ to 14 in., strokes up to 22 ft and 17 mounting styles. Information on high temperature operation is a feature.

62. Hydraulic Seals

Minnesota Rubber & Gasket Co.—Composition, specifications, applications and advantages of Quad-rings, injection molded hydraulic seals, are found in 10-page illustrated folder. Installation methods, typical applications and instructions for finding correct groove dimensions are detailed.

63. Electric Counters

Production Instrument Co.—Heavy duty electric counters designed for 200 million count life and tested at 1000 counts per minute are described in 4-page bulletin ECB-44. They are made in base and panel mounts and dustproof enclosed types for 25, 40-50, 60 cycle and direct current service on voltages up to 230.



. . . and runs up to 120 million operations without attention.

HELPFUL INFORMATION FOR THE TECHNICALLY MINDED . . .

Dimensions: Length, 1 ¾"; height, 1 5/16" to 1 ¾" (depending upon the number of contact springs); width, 1".

Operating Voltage: Up to 175 volts, dc, only.

Contact Spring Capacity: Maximum of 9 springs per pile-up.

Springs: Can be made of phosphor-bronze, "Bronco" metal, or other special purpose materials, as required.

A new stainless-steel armature bearing pin, a new sintered metal yoke, a new lubricating system for the armature—these features add up to 10 times the life of former relays. Automatic Electric Printed-Circuit Relays meet today's needs in automation, in computers, in any applications requiring utmost dependability.

Specially designed plug-in terminals are an integral part of the coil and of the contact springs. They make firm, tight, high conductivity connections with printed circuits—and may be permanently secured by using any recognized soldering technique.

Besides these features, you get efficient magnetic design, permanently welded contacts, "stay-put" contact springs and many other advantages found in all Automatic Electric relays. Save parts, assembly and wiring time by using printed circuits—and Automatic Electric Printed-Circuit Relays. For complete details, *write:* Automatic Electric Sales Corporation, 1033 West Van Buren Street (HAymarket 1-4300), Chicago 7, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. *Offices in principal cities.*

RELAYS **SWITCHES**

AUTOMATIC ELECTRIC

ORIGINATORS OF THE AUTOMATIC DIAL TELEPHONE

CHICAGO

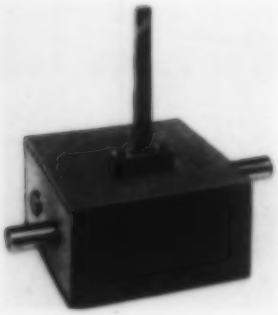
NEW PARTS AND MATERIALS

For additional information on these new developments, see Page 247

Reversing Clutch Unit 64

rated 3 hp at 200 rpm

Mechanical reversing at full speed is possible with this reversing clutch unit, which is rated 3 hp at 200 rpm. Control can have 1:1 ratio in both forward and reverse, or 2:1 ratio reversing at higher or lower speed than original. Lever positions are forward, neutral and reverse. Unit is enclosed in oil-



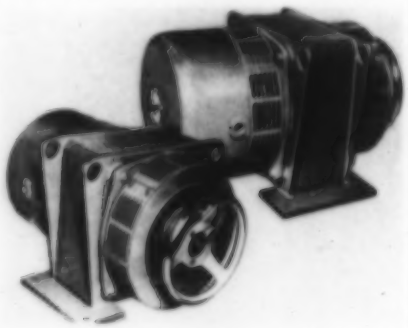
tight, dust-free housing. The 65-lb unit can be mounted in any position. Made by **Atlas Industrial Corp.**, 849 39th St., Brooklyn 32, N. Y.

Circle No. 64, Page 247, for more data

Adjustable-Speed Motor 65

operates on ac

Model N-S adjustable-speed motors can be equipped with completely automatic, semi-automatic or manually operated controls. Operating efficiency is maintained under conditions ranging from sudden stops to reversing or inching. Motors are available in sizes which provide from 0.5 to 1250 hp, with speed ranging from 30:1 to 1.5:1. They are adapted to high starting torque



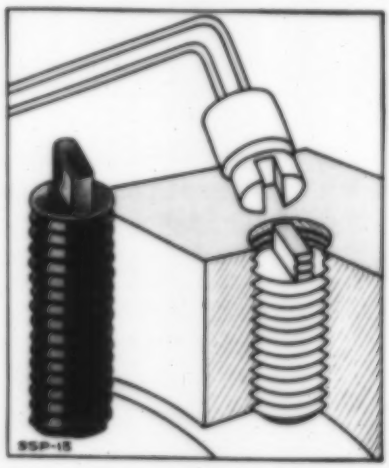
loads and operate on three-phase, 50, 60 or 400-cycle ac. Produced under license from Laurence, Scott & Electromotors Ltd., England, by **Bogue Electric Mfg. Co.**, 52 Iowa Ave., Paterson, N. J.

Circle No. 65, Page 247, for more data

Setscrews 66

slab head sets flush with surface

These Flush-Lok slabbed head setscrews are designed for applications in which the slab portion cannot extend beyond the tapped hole. They lock positively in all positions. Screws are made with an



undersize slab and are removable with a special wrench which is provided. They also can be supplied in the Nu-Cup design, which provides holding power advantages of 42 per cent sharper angle, and is suitable for hopper feeding. Made by **Set Screw & Mfg. Co.**, Main St., Bartlett, Ill.

Circle No. 66, Page 247, for more data

Rotary Joint 67

introduces fluids to rotating parts

Introduction of fluids under pressure from a stationary source to rotating equipment is made possible by line of standard fluid

transfers. Typical uses are transferring coolant to drills and the introduction of pressurized fluids to cylinders or clutches on hydraulic equipment. Fluid pressures range up to 1000 psi, and shaft speeds can be up to 10,000 rpm. Shielded, prelubricated bearings and balanced pressure seals are incorporated. Made by **Sealol Corp.**, 197 Post Rd., Providence 5, R. I.

Circle No. 67, Page 247, for more data

Precision Couplings 68

multiple-jaw type

Type N4 multiple-jaw couplings are used for manual or mechanical engagement and disengagement of shafts or unit assemblies. De-

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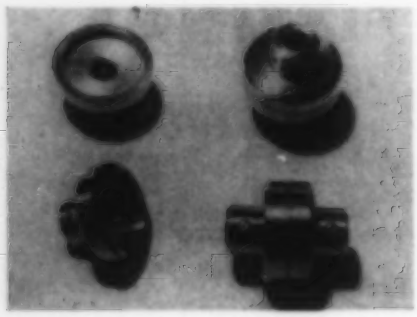


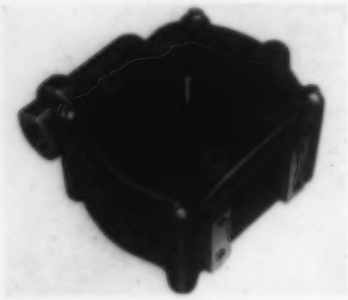
signed for ⅛, 3/16 and ¼-in. diameter shafts, the couplings are made of No. 303 stainless steel, passivated. They have stainless steel setscrews for holding and subdrill holes for fixed pinning as required. Combinations of dissimilar shafts are also available. Made by **PIC Design Corp.**, 160 Atlantic Ave., Lynbrook, L. I., N. Y.

Circle No. 68, Page 247, for more data

Rotary Solenoid 69

usable on 110-v, 60-cycle ac

Possessing force characteristics of linear solenoids, this rotary solenoid is essentially a toroidal coil system wound on a stator and a shaft-mounted rotor. Standard



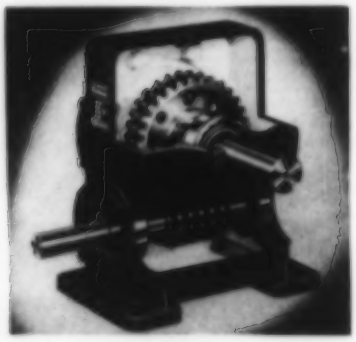
electrical rating is 115-v, 60-cycle ac; other voltage and frequency ratings and dc types are available. The pure rotary movement of the shaft simplifies application. Eight basic sizes provide a wide range of forms, offering torque values from fractional to 62.5 lb-in. at maximum stroke on continuous-duty models. Intermittent-duty models for higher torque values are available. Stock models give 20, 30 and 45-degree rotation, and rotation up to 60 degrees can be provided. Made by **Lee Spring Co.**, Leetronics Div., Dept. 94, 30 Main St., Brooklyn, N. Y.

Circle No. 69, Page 247, for more data

Speed Reducers 70

available in single and double reduction types

Nine models in line of series C speed reducers provide 108 sizes. They are available in single and double reduction worm-gear types, as well as in double reduction, worm and helical gear type. Horsepower range is 0.018 to 34.14, with reduction ratio range of 5:1 to 4460:1. Maximum output torque range is 103 to 34,767 lb-in. Design of housing provides high thermal capacity and vibrationless



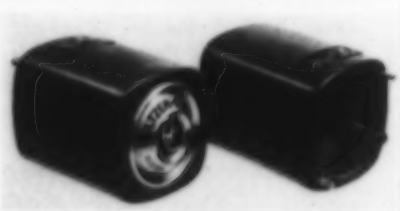
mounting. Tapered roller bearings and large shafts are used to give high load carrying capacity. Made by **Winsmith Inc.**, 10 Eaton St., Springville, Erie County, N. Y.

Circle No. 70, Page 247, for more data

Miniature Motor 71

housed in a 3-in. diameter frame

Most models in this new line of synchronous motors are of the single-value capacitor type, for single-phase operation. Efficiencies of various ratings are over 30 per cent. The motors have stainless steel shafts. The design is



basically the reluctance type, but the rotor is completely cylindrical with no irregularities or slot openings. The stator is of slotted construction with distributed windings and Mylar insulation. End caps are die-cast aluminum. Either ball or sleeve bearings are available. Ratings for continuous duty range from 1/200-hp at 1800 rpm to 1/60-hp at 3600 rpm in the synchronous type and 1/100-hp at 1700 rpm to 1/50-hp at 3400 rpm in the induction type. Made by **National Pneumatic Co. Inc.**, Holtzer-Cabot Motor Div., 125 Amory St., Boston, Mass.

Circle No. 71, Page 247, for more data

Molded Rod and Tubing 72

X-rayed to detect defects

Molded Kelon-F is available in rod in sizes from ⅝ to 5 in. OD and in tubing in wall thicknesses from ⅜-in. The rods and tubes are X-rayed to detect cracks, internal strains, bubbles or porosity. Possessing excellent chemical, electrical and thermal properties, parts made of this material are suitable for severe applications involving corrosive chemicals and solvents in the temperature range from −300 to 400 F. The material is chemically inert and nonadhesive. Typical parts made from the rod and tubing are gaskets, low-temperature

seals, O-rings, probes, transformer terminals and valve seats. Made by **Shamban Engineering Co.**, 11617 W. Jefferson Blvd., Culver City, Calif.

Circle No. 72, Page 247, for more data

Vibration Mounts 73

control sway and thrust

Helical steel springs, rubber thrust bumpers, nylon dampers and steel base plate with sway control assemblies are combined in this Finn-flex type SB vibration mount. A dual-purpose bolt secures mounting to machine and also provides a means of leveling. Nylon-lined,

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MO-BIL-AC* (mobile a-c power supply) driven by vehicle engine, supplies up to 10 KW at 110-220 volts . . . .

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This unique S-K development also insures excellent transient response; upon application of full load, voltage recovers in one second or less. Speed of prime mover is not critical because regulator keeps output voltage proportional to output frequency. Thus, standard motors may be operated over a wide frequency range without overheating.

MO-BIL-AC is available in 3, 5 and 10 KW ratings, 60 cps, single and polyphase, any commercial voltage.

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precompressed, cylindrical rubber bumpers absorb thrust in any horizontal direction. Optimum damping is provided by nylon liners. Wear is taken up and adjustment maintained automatically. Proper sway control can be set by adjustment of self-locking control nuts. Base plates are rubber-bottomed to eliminate "creeping." Forty-one sizes range in load capacities from 100 to 6500 lb. Made by **T. R. Finn & Co.**, Industrial Div., 200 Central Ave., Hawthorne, N. J.

Circle No. 73, Page 247, for more data

Rotary Switches 74

with eight positions

Rotary switches for tap, transfer or selector applications are rated at 30 amp, 230 v ac and can be furnished with up to five poles. In the JD type, which has positive detent action, rotor movement can be limited to any number of positions up to eight, with or without an off position, or rotor movement

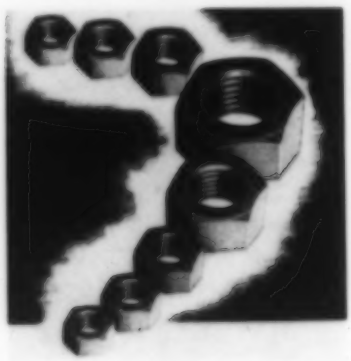
can be unlimited in both directions. In the JS type, a coiled spring mechanism provides snap-action make and break. This switch is available with unlimited rotation in both directions to utilize the full eight positions, or action can be limited to two, three, four or five positions. Nonshorting, knife-blade contacts are enclosed in molded phenolic disks. Screw terminals are provided for feeder and load contacts. Operating shafts are insulated. Switches are designed for mounting behind a panel. Made by **Electro Switch Corp.**, 167 King Ave., Weymouth 88, Mass.

Circle No. 74, Page 247, for more data

Semifinished Nut 75

hot-formed type made in ten sizes

These semifinished hot-formed nuts are produced without tool marks, rough edges and pitted cold work areas. They are made to close



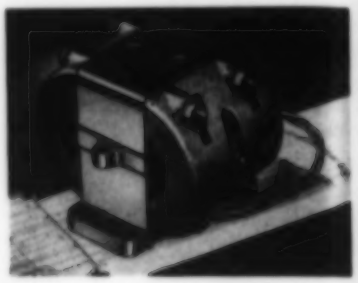
tolerances by the upsetting process and are said to be geometrically perfect. Ten sizes, from ½ to 1½ in., are available. The nuts can be galvanized, plated, or painted. Proof loads according to ASTM standards range up to 210,000 lb. Made by **Pittsburgh Screw & Bolt Corp.**, 2719 Preble Ave., Pittsburgh 30, Pa.

Circle No. 75, Page 247, for more data

Small Torque Motor 76

has fast response and high ouput force

Model 21 torque motor is designed to drive hydraulic servo valves or other mechanisms which require fast response and high output force in proportion to input current. Rated at 9 lb of force for 40 ma differential current, it may be driven from two miniature output tubes operating in push-pull or from magnetic amplifiers. The



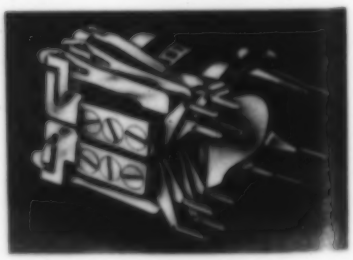
±0.015-in. stroke of the motor is proportional to input differential current. Displacement sensitivity is ¾-in. per amp, or 20 ma for full stroke. The motor is assembled with steel dowels and will withstand severe vibration. Position of the balanced armature is not affected by large lateral accelerations. This motor operates at temperatures from −65 to 400 F. Made by **Raymond Atchley Inc.**, 2340 Sawtelle Blvd., Los Angeles 64, Calif.

Circle No. 76, Page 247, for more data

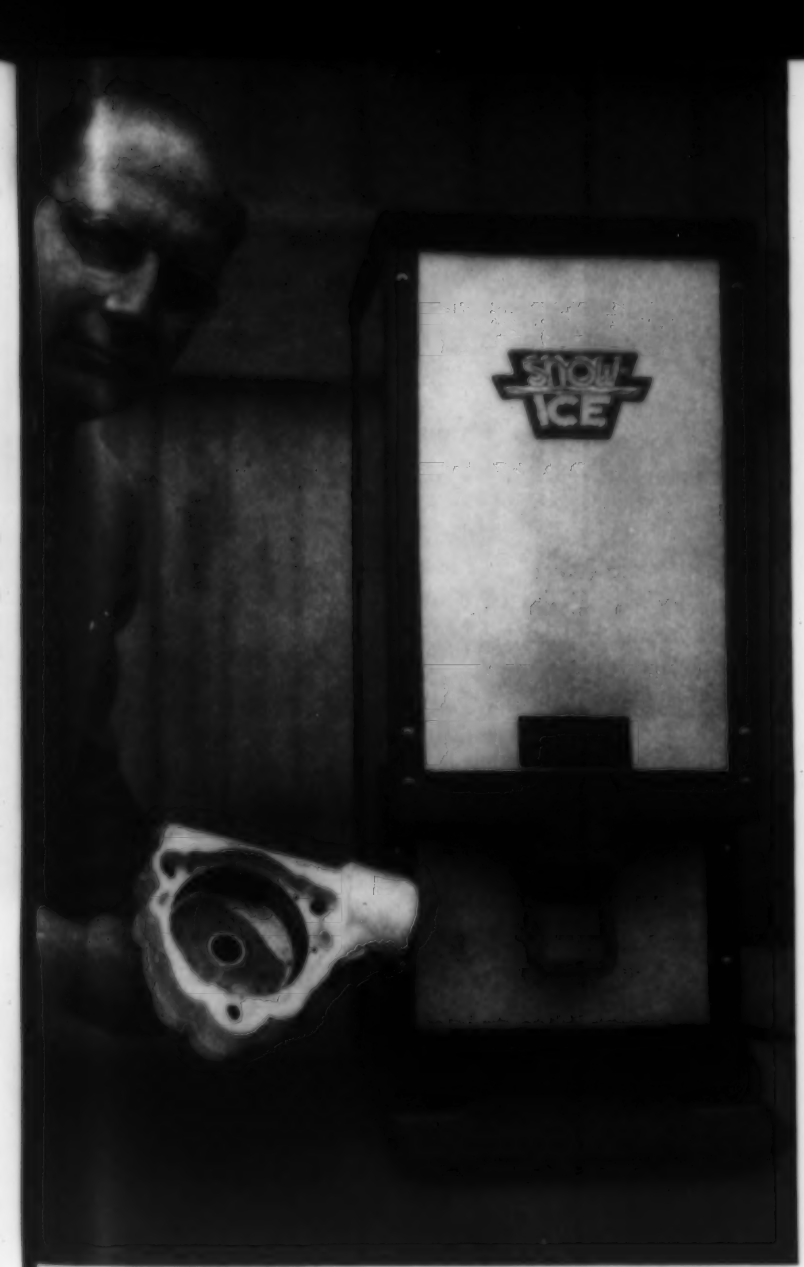
Miniature Relay 77

for direct plug-in use in printed circuits

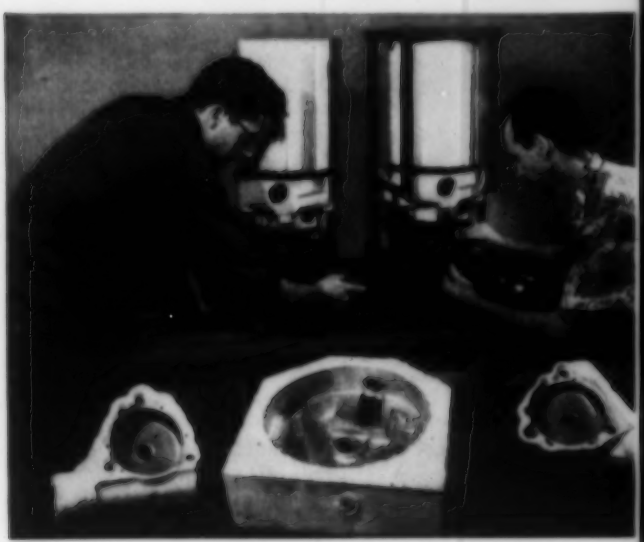
Design of the series SQD printed circuit relay permits direct insertion of relay terminals into the printed-circuit board, ready for immediate soldering. The plug-in termials are integral parts of the coil terminals and contact springs to assure continuity and provide good conductivity. The two contact arms of the relay permit two spring pile-ups of up to nine springs each. The relay has a heavy-duty bearing and bearing



pin. It is resistant to vibration, humidity and extremes of temperature and is capable of more than 100 million operations without readjustment or relubrication. It is 1¾ in. long, 1 in. wide and 1 5/16 to 1¾ in. high, depending on the number of contact springs



Gear case, bowl and hopper castings are insulated with a ½" thick shell of Dylite expandable polystyrene. Pre-expanded Dylite beads are placed in a mold around the castings. 270° F. steam further expands the beads, binding them tightly to the castings. The completely insulated parts are then assembled in the machine.



"It was not possible to produce this machine before Dylite* Expandable Polystyrene"

says **William L. Parsons,** *Asst. to the President, Brockman Tool & Manufacturing Co., Bala Cynwyd, Pennsylvania*

"They laughed when we wanted to make a counter type snow ice machine," said Mr. Parsons. "The almost impossible problem lay in finding an insulation that would prevent condensation from forming on the machine. We needed a material to meet these critical requirements: high insulating value, light weight, low thermal conductivity, high strength, easy moldability and production handling.

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"The use of Dylite insulation in our machines has increased the life of the ice by 100%, reduced insulation cost by 37%, eliminated troublesome condensation, minimized damage to electrical motors and wiring, prevented rust and mildew, curtailed maintenance, cut production costs, permitted a more compact package, lowered the weight and, has given us the finest, most efficient unit on the market today."

The unusual physical properties of Dylite expandable polystyrene make it perfect for all types of insulation applications. This new material is also being used for packaging, displays, toys and buoyant marine equipment. For more information send for our free illustrated booklet today. Koppers Company, Inc., Chemical Division, Dept. MD-105, Pittsburgh 19, Pennsylvania.

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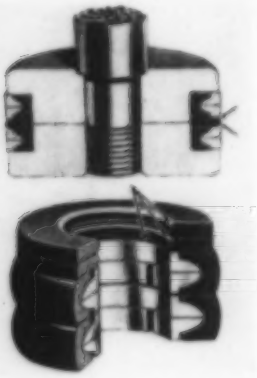
used. Made by **Automatic Electric Co.**, 1033 W. Van Buren St., Chicago 7, Ill.

Circle No. 77, Page 247, for more data

Rod, Piston Packings 78

have new type of chamfer on wiper surfaces

Redesigned Monopak hydraulic and pneumatic rod and piston packings now incorporate a chamfer on the wiper surfaces of the sealing rings which prevents ring extrusion and resultant braking action under heavy pressure. The new chamfer



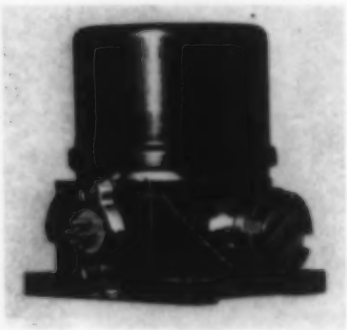
also provides a trap for any minute particles of foreign matter that escape the rod cleaning device. Made by **Hydraulic Accessories Co.**, 24301 Hoover Rd., Van Dyke, Mich.

Circle No. 78, Page 247, for more data

Servo Valves 79

for 500 to 3000-psi hydraulic systems

Line of electrically actuated, high-response hydraulic servo valves is available for 500 to 3000-psi hydraulic systems. Controlled maximum output flows are 0 to 9 gpm with a time constant of approximately 1.5 milliseconds from input differential current to output flow. The valves can be provided with various manifold configurations, coil inductance and resistance requirements in the same basic envelope, or to meet individual specifications. Construction incorporates a floating armature located above two vertically-placed nozzles. Thus, only the torque output of the motor restricts the motion away from any one nozzle. Weighing less than 1 lb each, the valves are made with steel bodies and integral steel inserts. They function with low leakage and high stability under extremes of temperature. Made by **Bendix Aviation Corp.**, Pacific Div., 11600 Sherman Way, North Hollywood, Calif.



Circle No. 79, Page 247, for more data

Control Transformers 80

small, lightweight Class B units

New design of control transformers incorporates Alkanex wire and a new method of frame design to reduce weight and size up to 40 per cent. Welded construction and a new clamping structure provide

high mechanical strength and good electrical characteristics. Frame size is related to volt-ampere capacity; within each frame size, a wide variety of voltage combinations is available. Units are available in dual frequency (50 or 60-cycle) and series-multiple ratings. The 11 transformer frame sizes presently available include ratings of 25 va through 2 kva for conduit wiring and 25 va through 250 va for open wiring. Transformers are impregnated by means of vacuum and pressure with varnish, which also acts as a bonding agent for the laminations. Made by **General Electric Co.**, Specialty Transformer Dept., Schenectady 5, N. Y.

Circle No. 80, Page 247, for more data

Small Swivel Joints 81

for intermittent turning

Two types of Swivel-ette joints are made either for free turning or with torque, which is controlled by turning an Allen head screw to actuate an internal brake shoe. The die-cast, Zamak 5 alloy joints are available in ½ and ¾-in. internal pipe sizes. Intended for occasional or intermittent turning,

they rotate 360 deg. Fittings are rated at 300 psi cold working pressure for water, oil and air. Operating temperature limit is 225 F. Made by **Emsco Mfg. Co.**, P. O. Box 2098, Terminal Annex, Los Angeles 54, Calif.

Circle No. 81, Page 247, for more data

Potentiometers 82

combine accuracy and compactness

Series C-158 precision ganging potentiometers are contained in 1⅝-in. diameter anodized aluminum housings. Power dissipation is 3 w. Rotation is continuous or brush-limited to stop on overtravels; electrical rotation is 320 deg, ±3 deg on standard units. Brush, collector and tap contacts are precious metal; slip ring and terminals are

March 19-23

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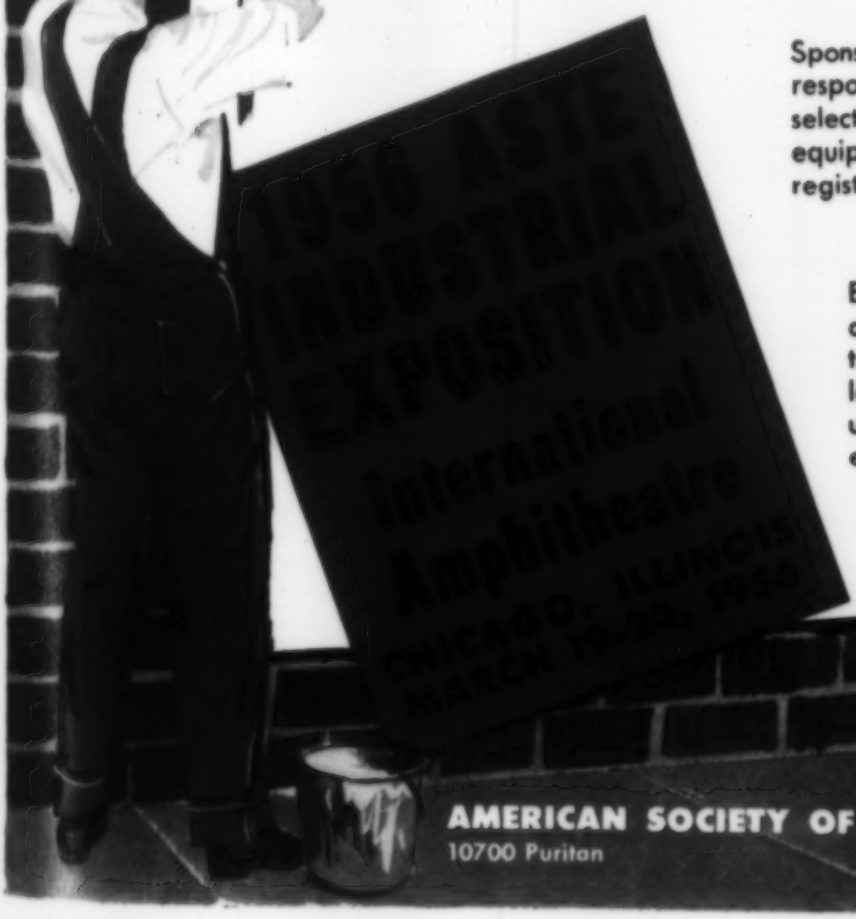

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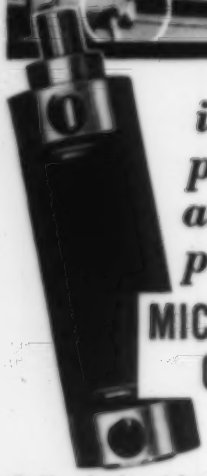
O-M

CYLINDERS
(air and hydraulic)



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MICHIGAN TOOL COMPANY

O-M cylinders (shown here installed on an automated speeder) are an integral part of "Gear-O-Mation" at Michigan Tool Company. In their automatic gear production line, O-M cylinders provide the muscle in the movement or holding of parts.

Important factors in Michigan Tool's choice of O-M cylinders for these machines were: *COMPACTNESS OF DESIGN* — their cleaner, more streamlined construction that allows installation in less space; *LESS MAINTENANCE* — easier to clean, inspect, remove, disassemble and service, if necessary, with no special equipment or skills needed. Knocks out downtime, keeps loading equipment in continuous operation.

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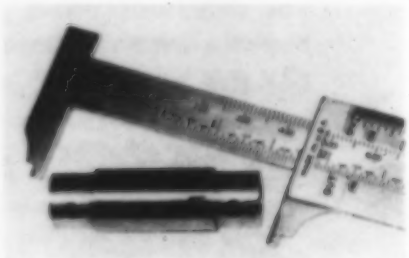
gold-plated. Multiple ganged units can be electrically phased independently without disassembly. All single and ganged assemblies are completely enclosed by permanent dust covers. Both threaded bushing and servo mounting types are available. Available from **DeJur-Amsco Corp.**, Electronic Sales Div., 45-01 Northern Blvd., Long Island City 1, N. Y.

Circle No. 82, Page 247, for more data

Miniature Clutches 83

have positive displacement drive

Line of precision clutches is designed with a positive displacement drive that will transmit up to 10 lb-in. of torque at speeds up to 1800 rpm, without external lubrication. Drive operates at higher



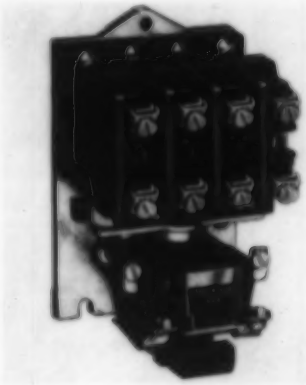
speeds in an oil bath. Single-revolution, overrunning, nonreversing and indexing types of clutches are available. Both sleeve-end and through-shaft mounts are available in these four types. Measuring 1¾ in. long, the clutches are suitable for use in packaging equipment, business machines, servomechanisms and computer devices. Made by **Precision Specialties**, 1342 E. 58th St., Kansas City 10, Mo.

Circle No. 83, Page 247, for more data

Heavy-Duty Relays 84

models with 2 to 12 poles

Each pole in type PM heavy-duty control relays is mounted in an individual melamine block. They are individually removable and replaceable. Rated at 10 amp, models are available with 2 to 12 poles. Enclosure of the poles on top forms a continuous melamine shelf on which wiring can be run. Two basic sizes cover all ordinary needs from two to eight poles, and two magnet coils for a given voltage will cover almost any combination of normally-open and normally-closed contacts up to eight poles. Conversion from normally-open to



normally-closed, or the reverse, can be made in the field. Pressure type terminals are wide enough for three No. 12 wires, with or without staked connectors. Made by **Clark Controller Co.**, 1146 E. 152nd St., Cleveland 10, O.

Circle No. 84, Page 247, for more data

Induction Motor 85

starts fast with 18 oz-in. torque

This capacitor type induction motor has a squirrel cage rotor and is designed for fast starting and smooth running. It operates on 115 v, single phase, 60 cycles with a worm gear reduction developing an output torque of 10 oz-in. at 33 1/3 rpm. At this load, it draws 0.140-amp and 16 w. At maximum load of 40 oz-in. speed

is 28 rpm. Starting torque is 18 oz-in. Field and rotor are mounted in a die-cast aluminum frame of which the gear box is an integral part. Precision gear reduction is built-in. Gears are sealed in silicone lubricant to provide constant performance over a wide range of temperature. The motor can be mount-

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Now you can use Rollpin to cut assembly and maintenance costs in a whole new group of applications. A new line made of beryllium copper, one of the strongest of the copper base alloys, opens the door to a wide variety of uses where resistance to corrosive attack, good electrical properties and other unusual characteristics are required. These slotted tubular copper spring-pins can be used in assemblies that range from plumbing fixtures to electrical instruments, particularly in conjunction with other copper base alloy components.

Rollpin has already established its ability to replace taper pins, straight pins and set screws; to serve as a rivet, dowel, hinge pin, cotter pin or stop pin . . . eliminating special machining, tapping and the need for hole reaming or precision tolerances. Driven into a hole drilled to normal production standards, it locks securely in place, yet can be readily drifted out and reused whenever necessary.

Rollpin is available in beryllium copper from .062″-diameter to .250″-diameter, and in steel and stainless steel up to .500″-diameter.

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Dept. R35-104 Elastic Stop Nut Corporation of America
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HYPOID—Sizes from 1½" to 28" dia.

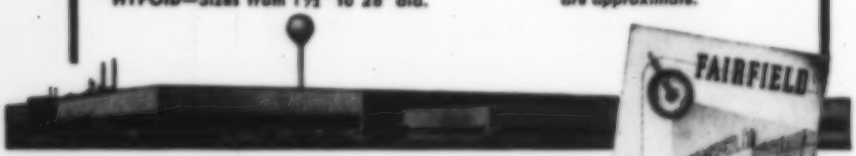
ZEROL—Sizes from 16 pitch, 1½" dia., to 1½ pitch, 21" dia.

WORMS AND WORM GEARS—Worms to 7" dia. Worm gears to 36" dia.

SPLINED SHAFTS—Lengths to 52". Diameters from 1" to 6".

DIFFERENTIALS—10,000 to 300,000 inch pounds capacity.

Note: All of the sizes above are approximate.



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ed in any position when equipped with lubrication seals. Made by **SoundScriber Corp.**, 146 Munson St., New Haven 9, Conn.

Circle No. 85, Page 247, for more data

Indicator Lights 86

for pilot and control use

Compact oil-tight pilot lights are designed for severe industrial service. They have retained oil-resistant gaskets and offer selection of several shapes of omnidirectional glass lenses, disks with letters or numbers inserted behind flat glass

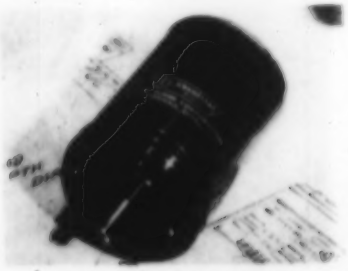
lenses to deliver specific messages, wide choice of incandescent or neon lamps with screw or bayonet type bases, choice of lens colors, and mounting in either 1 13/16 or 1-in. clearance hole. Made by **Dialight Corp.**, 60 Stewart Ave., Brooklyn 37, N. Y.

Circle No. 86, Page 247, for more data

Potentiometer 87

is also a variable transformer

This 400-cycle ac potentiometer, for use in servo systems and analog computers, combines characteristics of both a potentiometer and a variable transformer. Output impedance of less than 130 ohms eliminates the need for isolation amplifiers in many applications. Phase shift is also low. Size and mounting dimensions are designed to Bureau of Ordnance specifications for a size 18 synchro, and provision is made for coupling with synchros, resolvers and other



A Control Factor in Performance!

RESEARCH • DESIGN • METALLURGY • PRECISION MANUFACTURING

One of our biggest product transportation systems is seldom seen . . . because it lies below the surface. Countless miles of pipelines carry gases and fluids to every corner of the country. Gas, gasoline and diesel engines are the muscles that power the pumping and delivery systems. Our contribution to this day-in, day-out operation is the manufacture of quality bearings for engine dependability. We are a supplier to America's builders of industrial engines. **FEDERAL-MOGUL DIVISION,** Federal-Mogul-Bower Bearings, Inc., Detroit 13, Michigan.

SINCE 1899

FEDERAL-MOGUL
DIVISION

How to cut machining time on hard, tough parts like these

A STEEL can be hard and tough without needing to be hard and tough *to machine*. If you need such a steel for slitter knives, machine tool parts, pump parts, or other parts where wear resistance and strength are important, get Timken 52100 steel.

Its fully spheroidizing structure makes 52100 easy to machine. And without sacrificing strength or hardenability!

This high-carbon analysis alloy steel has high fatigue and tensile strength as well as good hardenability throughout its cross section. Timken 52100 steel will withstand working pressures up to 200,000 p.s.i., and can be oil quenched to a maximum hardness of 65/66 Rockwell C. in normal sections.

Rigid quality control at every step in production is your assurance of uniform quality in every shipment. The Timken Company pioneered the production of 52100. We are one of the world's largest producers of 52100 and the *only* source of 52100 steel in three finished forms—bars, tubes and wires. And for small run or emergency requirements, the Timken Company maintains a mill stock of 101 sizes of 52100 tubing, ranging from 1" to 10½" O.D.

For a stock list of available sizes, grades and finishes, write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING

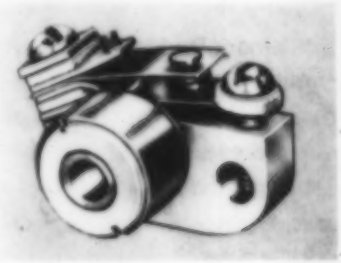
components, as well as for ganging. Shaft seals can be supplied. Precise operation is assured by use of accurately machined aluminum housings, close-tolerance ball bearings and centerless ground shafts. Standard linearity is 0.05-per cent. The unit is 1.75 in. in diameter by 2.68 in. long and weighs 10 oz. Made by **Perkin-Elmer Corp.**, Vernistat Div., Norwalk, Conn.

Circle No. 87, Page 247, for more data

Centrifugal Governor 88

handles speeds to 21,000 rpm

This miniature centrifugal governor for fractional - horsepower motors is unaffected by fungus or humidity and is designed for use on 30-v dc or 110-v ac motors. Contacts open when a preset speed is exceeded, and when speed drops below this set value, the contacts



close again. It has platinum contacts, coin silver-plated commutator, beryllium copper springs and aluminum body. It is factory set to operate at one specific speed in range of 6000 to 21,000 rpm. Setting is adjustable to ±1500 rpm. Speed regulation is ±2 per cent. Made by **Nader Mfg. Co.**, 2661 Myrtle Ave., Monrovia, Calif.

Circle No. 88, Page 247, for more data

Enclosed Motors 89

have virtually indestructible rotors

Line of rerated totally-enclosed, fan-cooled motors includes units in the 1 to 5-hp series, for both single phase and polyphase operation. Motors can be used in atmospheres laden with dirt, dust, fumes and mist. They meet all NEMA requirements and incorporate a virtu-

(*Continued on Page* 268)

Photo by Rensselaer Polytechnic Institute

Actually, how does a ball bearing work?

The world is full of ball bearings, yet here is a professor at a well-known engineering institute asking a simple question like that. The world is also full of simple questions about motion where everybody thinks that somebody must know the answer but nobody really does until a fellow comes along with a high speed movie camera and finds out for sure.

Camera photographs black dots painted on balls, as air turbine spins outer race. Inner race carries a load variable between 0 and 400 pounds. Illumination by indirect light prevents reflections from the balls.

Several thousand industrial firms are getting their answers—highly practical ones at that—with a Kodak High Speed Camera like the one above. It takes up to 3200 pictures a second. Viewing them at the usual 16 frames per second slows action down as much as 200 times. Some users make measurements on the film, others keep running the film over and over again to study some complex motion, but most have seen all they need to by the time the projector gets to the end of the reel.

We can send a booklet called "High Speed Motion Picture Making in Industry" that tells how some of these firms use the idea. Write *Graphic Reproduction Division,*

EASTMAN KODAK COMPANY, Rochester 4, N. Y.

the Kodak *HIGH SPEED* Camera

Kodak

TWENTIETH CENTURY Relay

The Potter &

Relays operating in special constructed ovens are subject to temperatures exceeding 400° Fahrenheit. Recording instruments indicate any malfunction.

One of the reasons that keeps Potter & Brumfield Relays out in front.
The best Engineering design is not enough.
Prototypes must pass all torture qualification tests.
More important the manufactured product must meet engineering expectations. Not just now and then, but for as long as the relay is made.
That is why Potter & Brumfield relays are tortured regularly throughout production runs.

POTTER & BRUMFIELD

Frost covered sealed relays are taken from especially designed sub-zero chamber which has subjected them to continuous operation at —100° Fahrenheit.

Shaker and power supply located in soundproof room has frequency range of 0 to 2000 C.P.S. Complete with automatic servo control of acceleration and frequency cycle.

ALL TYPES—ALL SIZES—FOR ALL APPLICATIONS

Torture

Brumfield Way

Different relay designs are subjected to torture tests in varying degrees.
Potter & Brumfield builds relays to all quality levels and at the best possible price to you.
Samples available for immediate delivery. Send your specification for recommendation and quotations.

For quick delivery over 350 different standard relays stocked by 500 Franchised Electronic Parts Distributors throughout the United States and Canada.

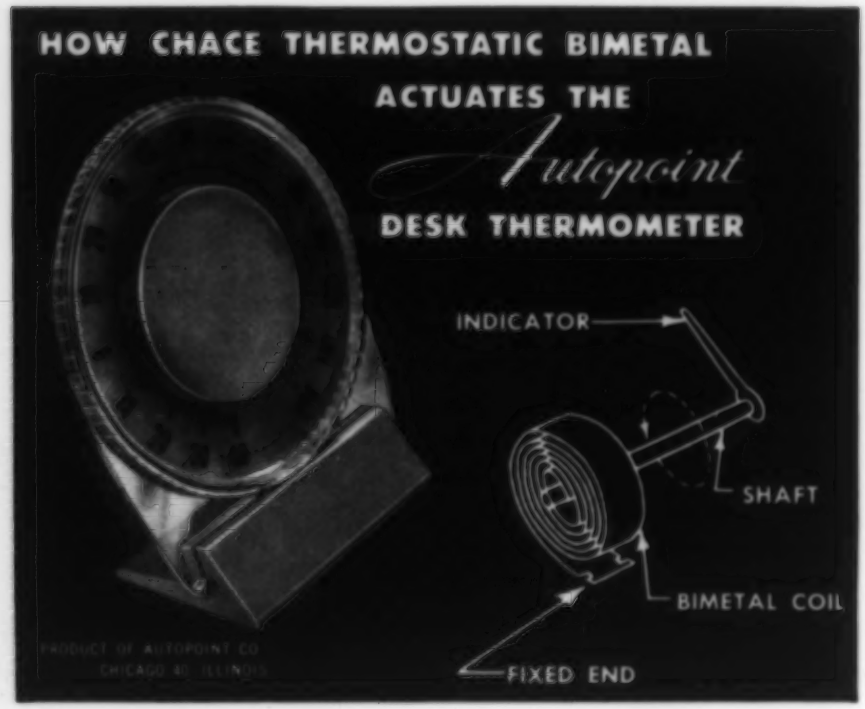
Typical rugged life test using a series of 1000 watt lamps causing the relay to operate under a load 10 times more severe than normal.

PRINCETON, INDIANA

Control of metal finishes are a must for accurate relay operation. Parts are periodically subjected to a minimum 20% salt spray to check their resistance to corrosion.

Tester built to JAN specifications provides shock of over 100 G's. Contact reactions are indicated on oscilliscopes—thyratrons or other special equipment depending on speed.

ALL TYPES—ALL SIZES—FOR ALL APPLICATIONS



The Autopoint Desk Thermometer illustrates one of the simplest applications of a bimetallic element—that of operating an indicator over a predetermined temperature range. The coil of Chace Thermostatic Bimetal which actuates this device is calibrated at the factory to assure precise temperature readings over a long period of time. Since this thermometer is also used to indicate more extreme outdoor temperatures, it has an effective range of −40°F. to +120°F. This application requires a bimetal material with a high deflection range and high torque properties, such as is found in Chace No. 2400 Thermostatic Bimetal.

A coil of Chace Thermostatic Bimetal is securely anchored at its one end to the backplate of the thermometer. The other end of the coil is fastened to the stem of the dial indicator. Temperature variations between −40°F. and +120°F. cause the coil to rotate in a predetermined arc, moving the indicator to register the correct ambient temperature.

Chace Thermostatic Bimetal is available in 29 different types, in strip and coil forms, as well as in completely fabricated elements made to customer specifications. Write now for our free 36-page booklet, "Successful Applications of Chace Thermostatic Bimetal."

W. M. CHACE CO.
Thermostatic Bimetal
1616 BEARD AVE., DETROIT 9, MICH.

New Parts

(Continued from Page 265)

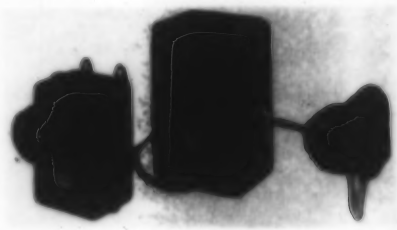
ally indestructible aluminum rotor, a ventilating fan which is designed to operate in either direction, six-layer insulation for stator windings, plastic-coated wire and brackets for bolting the motor to a machine, or vice versa. Made by **Century Electric Co.**, 1806 Pine St., St. Louis, Mo.

Circle No. 89, Page 247, for more data

Photoelectric Control 90

operates over distances up to 100 ft

Affording speeds up to 600 operations per minute, Set P4L photoelectric control system operates over distances up to 100 ft. It is usable for a wide range of remote control, safety, alarm and



other industrial applications and can be used with mirrors. Set has a remote phototube with an extended lens system. High sensitivity assures positive action under varying light conditions and interference caused by dust or vapor. Plug-in chassis simplifies maintenance and minimizes downtime. Made by **Electronics Corp. of America**, Photoswitch Div., 77 Broadway, Cambridge 42, Mass.

Circle No. 90, Page 247, for more data

Power Positioner 91

has cylinder which operates on 100-psi air

Positioning of proportioning pumps, electrical components, gov-

CARTER

Send for this COMPLETE FILE

FLUID POWER BULLETINS

Here is the most advanced line of fluid power cylinders and controls in the industry. Simplicity of design is the key to all the benefits you get with Carter units. Cartridge type construction makes for *fast,* simple replacement of parts. *This means less down-time, less cost to you.* These units are rugged yet compact, thanks to key-type construction — no tie rods, no bolts. All mounting styles available. Integral steel head and mount, completely interchangeable size for size, permits production economies, faster deliveries. Check into Carter today!

THESE CARTER ADVANTAGES MEAN BENEFITS TO YOU

- **Full 1 to 1 Meehanite rod bearings...easily replaced.**
- **Key-type stainless steel locking ring permits 360° rotation of pipe ports . . . removal of heads in a matter of seconds.**
- **Leakproof "O" ring seal, between head and cylinder wall.**
- **Integral cast steel head and mount.**
- **Spring loaded "V" packing on rod and gland.**
- **Precision honed heavy wall tubing...6 to 1 safety factor.**
- **Piston ring or cup packing construction.**
- **Perfect alignment . . . low coefficient of friction . . . high efficiency.**
- **Metal rod scraper, milled wrench flats, heavy duty, high tensile chrome plated piston rod . . . standard in all sizes.**
- **No increase in length for full cushioned cylinders.**
- **Spot-faced mounting holes for socket head cap screws.**

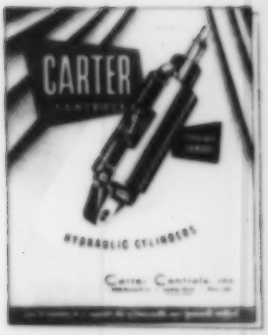
Carter Controls, inc.

2914 Bernice Road · Lansing, Illinois

GRanite 4-3305

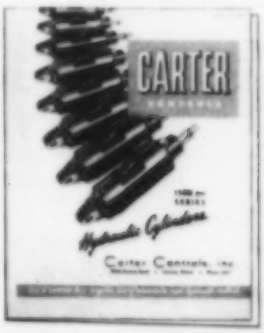
AIR CYLINDERS

Standard sizes 1½" thru 8"; stroke lengths to 18 feet; all standard mounting styles. Complete dimensions, specifications and parts data. All essential designing and ordering information. **Bulletin 100A.**



750 LB. HYDRAULIC

Complete range of standard sizes 1½" thru 8"; strokes to 18 ft.; all standard mounts. Complete details on parts, dimensions, and specifications. A light, compact cylinder for most design and plant applications. **Bulletin 750.**



1500 LB. HYDRAULIC

Carter's heavy duty hydraulic unit for pressures to 1500 psi. Bulletin gives full details on all standard sizes, 1½ thru 8". Strokes to 18 feet. Complete parts, dimensions and specification data. **Bulletin 1500.**

POWER PACK AIR CYLINDERS

The new Carter Power-Pack cylinder with built-in valve! Automates any operation. For solenoid, air-limit or remote air poppet control. Complete details in new **Bulletin 125.**

CARTRIDGE AIR VALVES

The new Carter cartridge air valve is compact, simple, and has many different applications. For operation with solenoids, lever poppets or palm poppets. Send for new **Bulletin V-150.**

CLAMP-TYPE CYLINDERS

The first all-steel, first line quality clamp cylinder to be offered at a competitive price. Incorporates all the rugged dependability of the standard Carter line. **Bulletin CT-1000.**

BALL BUSHING

The BALL BEARING for your

LINEAR MOTIONS

Sliding linear motions are nearly always troublesome. Thousands of progressive engineers have solved this problem by application of the Precision Series A or Low-Cost Series B BALL BUSHINGS.

Alert designers can now make tremendous improvements in their products by using BALL BUSHINGS on guide rods, reciprocating shafts, push-pull actions, or for support of any mechanism that is moved or shifted in a straight line.

Improve your product. Up-date your design and performance with BALL BUSHINGS!

Now manufactured for ¼", ½", ¾", 1", 1½", 2", 2½", and 3" shaft diameters.

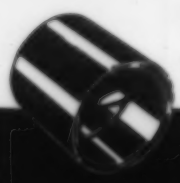
LOW FRICTION • LOW MAINTENANCE
ELIMINATES BINDING AND CHATTER
SOLVES SLIDING LUBRICATION PROBLEMS
LONG LIFE • LASTING ALIGNMENT

Progressive Manufacturers Use Ball Bushings —A Major Improvement at a Minor Cost

THOMSON INDUSTRIES, Inc.

Dept. E, MANHASSET, NEW YORK

Write for descriptive literature and the name of our representative in your city.



Also manufacturers of NYLINED Bearings — DuPont NYLON within a metal sleeve—for rotation and reciprocation.

New Parts

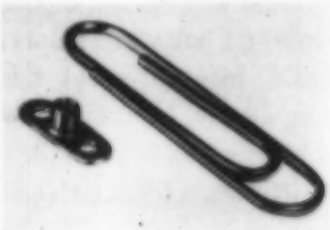
ernors and valves are included among applications for this model B-50 cylinder Conomotor. This pneumatically positioned power operator will produce stroke lengths up to 2 in. and thrusts of 300 lb in either direction. It uses supply air pressures up to 100 psi with a conventional 3 to 15-psi signal range. Made by **Conoflow Corp.**, 2100 Arch St., Philadelphia 3, Pa.

Circle No. 91, Page 247, for more data

Miniature Anchor Nut 92

made in 2-56 thread size

Kaylock self-locking anchor nut is now available in a 2-56 thread size. Locking design utilizes a positive principle, wherein the upper threads are made elliptical and



highly resilient. No auxiliary locking device is needed. The nut has high tensile strength. It is made entirely of metal and can be used at temperatures up to 550 F. Made by **Kaynar Co.**, Kaylock Div., 820 E. 16th St., Los Angeles, Calif.

Circle No. 92, Page 247, for more data

V-Belt Sheaves 93

variable-pitch type with interchangeable bushings

Maxi-Pich variable pitch V-belt sheaves are equipped with interchangeable tapered bushings to accommodate various prime mover shaft sizes. The standard control sheave is adjustable for either increase or decrease of pitch diameter while the machine is inoperative. Pitch diameter of the motion control sheave is adjustable while the machine is operating. Belt adjustment is accomplished

Reynolds
ALUMINUM REPORTER
★ ★ ★ Nineteenth in a Series to Industry on Aluminum Uses and Developments ★ ★ ★

ALUMINUM DIE-CASTINGS CUT UNIT COSTS UP TO 75% FOR BELL TELEPHONE LABORATORIES

Small Production Not Necessarily a Limiting Factor

Although aluminum die castings are a familiar cost saver in the manufacture of large quantity items, Bell Telephone Laboratories have recently effected a major saving using die-cast aluminum for limited production of carrier telephone equipment units.

Pointing out that generally an item of fair complexity with an annual demand of around 5000 probably justifies die-casting, L. Pedersen of Bell Laboratories nevertheless selected this method for producing several items with as small an annual requirement as 1000.

These units are part of the trend toward miniaturization of telephone equipment. In designing for this goal, the engineer benefits from the use of aluminum die castings because the various mounting surfaces, as well as small pockets or compartments are easily formed in the casting process without the need for machining or other fabrication steps. Properly designed, die-castings incorporate details that otherwise must be mechanically fastened to the fabricated framework. Equipment designations and control identifications can be incorporated in the die by using raised characters in recessed areas instead of by printing or identification plates. The uniformity of aluminum die-castings shows to great advantage on the assembly line. Misalignments and necessary adjustments typical in parts fabricated by other methods are eliminated with properly designed castings.

In addition, Bell selected aluminum because of its light weight, low cost, dimensional stability, good electrical shielding properties in the carrier frequency range, and the practical nature and pleasing appearance of the natural aluminum finish. Aluminum alloys form a thin transparent oxide surface film which, for many uses, is sufficient protection for the part, and no further finishing is necessary — an important item when cost is a design consideration.

Left. Three of the eleven die-castings in N1 carrier systems. Right. Completed assembly of the three castings.

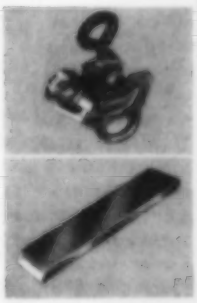
The requirement for N1 carrier systems is approximately 1000 a year. Eleven different aluminum die-castings are needed and a completed system requires from two to as many as twenty-four castings of one kind. Even assuming minor casting changes, Bell Laboratories found that the savings with aluminum die-castings would, if necessary, justify complete retooling after completion of 100 systems. With an annual demand of 24,000 for each of the three N1 castings, illustrated, costs were shown to be only about one-fourth those for other fabricating methods.

The group transmitting unit of the N1 system requires about 1000 die-cast chassis a year. With this relatively small demand, drilling and tapping a number of holes, and the part's share of the die cost amortized over a four-year period, the unit cost was only half that for other ways of fabrication.

Reynolds does not produce die-castings but will work with you to an unbiased solution of your design problems. For this assistance call your nearby Reynolds office listed under "Aluminum" in classified phone directories, or write to *Reynolds Metals Company, P.O. Box 1800-HR, Louisville 1, Kentucky.*

Aluminum in Composite Metals Finding More Important Applications

The many recognized advantages of aluminum are becoming increasingly important in composite metals to design engineers in many fields. Composite or clad metals have been widely used for many years—two of the oldest such composites are the clad high-strength aluminum alloys employed in the aircraft industry, and steel clad with aluminum to provide greatly extended life in high-temperature applications.



Top. Cable connector employing ALCUPLATE shims. Bottom. Rectangular wave guide tubing for radar work made of aluminum with coin silver lining and copper clad outside layer

One of the most recent applications indicating the important possibilities of aluminum-clad metals is the aluminum-clad low-carbon steel used to replace pure nickel in many electron tube elements. The clad metal not only replaces the nickel satisfactorily but reduces costs by eliminating the carbonizing operations required when using nickel.

Another composite metal of interest is ALCUPLATE, consisting of a layer of aluminum bonded to a layer of electrolytic copper by a solid phase bonding process which assures the absence of objectionable voids, oxides, and compound inclusions. The strength of the bond is equal to that of the aluminum. The most popular applications employ aluminum for 80% of the thickness, copper for the remaining 20%.

ALCUPLATE is an excellent conductor of heat and electricity since there is nothing between the aluminum and the copper to offer any resistance. This metal is especially useful in solving termination problems in electrical conductors where aluminum members must connect into copper fittings.

Another composite metal that has proved highly useful is ALSIPLATE, consisting of layers of aluminum and fine silver bonded together. ALSIPLATE tubing is widely used in radar and ultra high frequency radio work where the fine silver lining provides for highly efficient transmission of energy in wave guides carrying signals from transmitter to the antenna or radiator.

For more complete information, write for your copy of the Reynolds Technical Advisor, No. 30. to *Reynolds Metals Company, P.O. Box 1800-HR, Louisville 1, Ky.*

Delo Finds Aluminum Best For Screw-Machined Chair-Leg Caps

In manufacturing modern metal chair and table leg-caps for Troy furniture, the Delo Screw Products Company of Delaware, Ohio, has selected aluminum screw-machine stock. The superior machineablity of free-cutting 2011-T3 aluminum, its economy, and efficiency, all contributed to Delo's selection of aluminum for this screw-machine job.

As an interesting sidelight, even though these leg caps are gold anodized, the yellow metals were never considered for the job. Delo found that anodized aluminum will retain its bright finish, whereas the yellow metals have to be lacquered and the lacquer soon wears off, leaving a dull unattractive surface.

For the complete story on machining with aluminum, send for a copy of "Machining Aluminum Alloys". Free when requested on business letterhead. Write *Reynolds Metals Company, P.O. Box 1800-HR, Louisville 1, Ky.*

MORE INTERESTING NEWS ABOUT ALUMINUM ON NEXT PAGE
(Advertisement)

Faster-Welding Aluminum Lowers Labor Costs For Ballymore Safety Stepladder

The Ballymore Company of Wayne, Pennsylvania, recently announced a complete new line of aluminum Safety Stepladders to complement a steel line previously available. Ballymore says there has been an increasing demand from their agents and customers for safety ladders that are lightweight for easy handling, sanitary for food plants, non-sparking for explosive atmospheres and corrosion resistant for better appearance in every use. Aluminum provides all these advantages.

All-welded construction is featured in the new line of aluminum ladders which are available in seven, 1 to 4 step models. Frames are assembled from ½" IPS 6061-T6 aluminum pipe and 3/16"x1" rectangular 6061-T6 aluminum bar. Steps are formed from 3003-H14 aluminum sheet and have adhesive bonded rubber safety treads. Aluminum welding is done by the "Filler-Arc" method which Ballymore says is considerably faster than its steel welding operations and consequently has reduced labor costs.

Aluminum and welding bring many customer and production advantages to manufacturers of metal products. To help you capitalize on these advantages, Reynolds has prepared a 185 page handbook, "Welding Aluminum". Single copies of this fact-packed book are free when requested on business letterhead. Write to *Reynolds Metals Company, P.O. Box 1800-HR, Louisville 1, Ky.*

Reynolds Aluminum Atomized Powders Used as Fuel for Welding, Cutting and Scarfing

The insatiable hunger of aluminum for oxygen, and its ability to "forage" oxygen from normally stable oxides, makes it an excellent fuel with numerous industrial applications.

In finely powdered granular form — and in the presence of a suitable source of oxygen — the aluminum is capable of generating intensive heat for short periods of time. It can readily reduce such oxides as iron oxide, chromium oxide, calcium oxide, magnesium oxide and carbon dioxide. This property makes aluminum extremely valuable when used as a combined fuel and reducing agent in thermite welding and other chemical reduction processes.

Under correct conditions, it is possible to mix finely divided aluminum with metallic oxides and then ignite the aluminum. Because of the exothermic nature of the reaction, complete reduction of the metallic oxide can be accomplished without the need for additional heat.

In thermite welding, a mixture of aluminum and iron oxide powders or pellets is ignited. The metallic iron resulting from the reduction of the iron oxide flows into the area to be welded or repaired.

The quick high heat release of aluminum in powder form makes it ideal for cutting and scarfing. Several "guns" have been developed for this purpose. By the use of various types of nozzles, the flame of the burning aluminum can be narrowly focused, for exceptionally high accuracy.

These methods have found wide acceptance in cutting heavy scrap for remelting, for the preparation of slabs and billets from ingots, etc. And they are not limited to metals but will also cut concrete, fire brick and slag, and are said to be an economical means for reconditioning furnaces.

The same general principle applies to the use of aluminum powder in "powder lancing". Materials such as concrete, fire brick and sand and metal incrustations, as well as ferrous and non-ferrous metals and their alloys are easily pierced by powder lancing methods. As an example of the efficiency of these processes, a 12-inch concrete slab was pierced in one minute by using a mixture of aluminum and iron powders in a stream of oxygen.

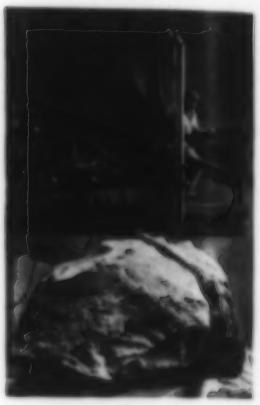


Photo Courtesy of Linde Air Products Company

Aluminum powder is extensively used in explosives. An oxidizing agent in the explosive mixture causes the aluminum to burn rapidly. The terrifically high temperature produced almost instantaneously from this reaction causes very rapid expansion of the explosive gases, resulting in greater shock.

For complete information on these and many other uses and types of aluminum powders, Reynolds has prepared an 84-page booklet, "Aluminum Powders and Pastes". Single copies are free when requested on your business letterhead. Write to *Reynolds Metals Company, P.O. Box 1800-HR, Louisville 1, Ky.*

WHAT'S NEW

A Quick Look at New Reynolds Aluminum Products and Applications

Aluminum Foil "Supports" Aircraft Carrier

Reynolds Aluminum foil is now being used by the Navy in the construction of the new 60,000 ton USS Ranger. The foil covers the wooden keel blocks on which the ship's steel hull rests, thus protecting the hull against rust due to moisture in the blocks. This is another dramatic example of the protective powers of aluminum foil—the same foil used in many industrial and commercial packaging applications.

Aluminum Sandwich Panel

Aluminum-faced honeycomb panels in several grades and a wide range of thicknesses and sizes are now manufactured by several firms. These panels are vermin-proof, rustproof, and exceptionally strong for their weight. They are used commonly for large signs and displays, for doors, movable partitions, curtain walls and insulated structures, and for furniture. A list of fabricators of Reynolds Aluminum faced honeycomb panels is available by writing Reynolds at the address below.

Consumers Look For Reynolds Design Seal

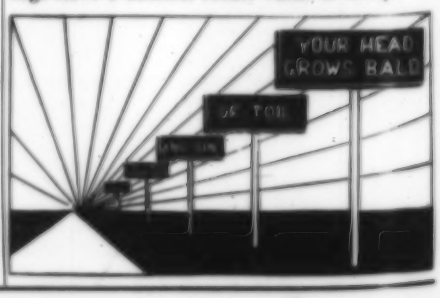
This "Designed In Reynolds Aluminum" seal is familiar in millions of homes, thanks to extensive television advertising. To consumers it means products manufactured with highest quality aluminum—makes buyers out of shoppers. For details on how your company can qualify for this seal, write Reynolds Metals Company at the address below.

Reynolds Publishes Guide to Electric Conductor Accessories

A new manual "A Guide to the Selection of Electric Conductor Accessories" provides information on accessories needed with aluminum wires and cables in constructing overhead transmission and distribution lines. (Reynolds does not make these accessories, merely lists them for your use.) For free copy, send to Reynolds at the address below.

Reynolds Aluminum Used for Shave Creme Jingle Signs

Reynolds Aluminum .006" thick sheet in 1235-H18 alloy and temper is now being used for the familiar roadside shave creme signs. The sheets are mill cut to correct size. After painting they are shipped to sign locations, where they are stapled to permanent boards. Previously 1" lumber boards had to be returned to the Minneapolis office for yearly repainting. Now fresh aluminum sign facings are sent out once a year with an anticipated savings of $25,000 in freight and handling charges. In addition, old discarded sign facings have a definite resale value as scrap.



FOR COMPLETE INFORMATION ON THESE OR ANY OTHER REYNOLDS ALUMINUM PRODUCT, write to Reynolds Metals Company, P.O. Box 1800-HR, Louisville 1, Kentucky

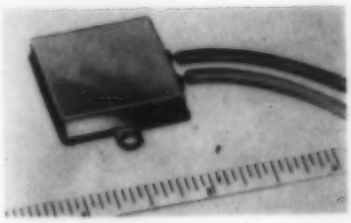
through the use of standard, pivoted or sliding motor bases. Sheaves are available in four types: *A* sections with pitch range from 3.5 to 8.0 in. and 2 to 6 grooves; *B* sections with pitch range from 4.0 to 9.9 in. and 2 to 8 grooves; *C* sections with pitch range from 8.4 to 15.4 in. and 2 to 8 grooves; and *D* sections with pitch range from 12 to 17 in., and 3 to 10 grooves. Made by **V-Belt Engineering Co. Inc.**, P. O. Box 9492, Richmond 28, Va.

Circle No. 93, Page 247, for more data

Thermal Switch 94

calibration range is −20 to 600 F

Made with a bimetal element and stainless steel case, this hermetically sealed thermal switch is designed for easy mounting on flat surfaces wherever skin temperatures must be controlled. It measures 1 x 1 x ¼ in., and is suitable



for high altitude application. Operating temperature range is −65 to 800 F. Switch is rated 2 amp on 115-v ac resistive, and factory set and sealed calibration range is from −20 to 600 F. Made by **Control Products Inc.**, 306 Sussex St., Harrison 12, N. J.

Circle No. 94, Page 247, for more data

Integral Rotor Pump 95

has integral cooling system

Model S series canned rotor, sealless centrifugal pump employs a circulation system wherein pumped fluid cools stator windings, rotor and bearings. Made with large bearing area, pumps are available with capacities up to 170 gpm and heads to 150 ft, with standard temperature and pressure limits of 350 F and 150 psi. They are available in ⅓ through 3-hp models, clad

(*Continued on Page* 276)

new precision in extended range vibration testing:

CALIDYNE'S

"HI-FI"

SHAKER SYSTEM

Precisely controlled vibration testing — over the *5 to 5000* cps frequency range at *full* rated output — is now a reality with Calidyne's new Series 8000 Shaker System. The Shaker itself incorporates an extremely rigid armature structure, designed to eliminate all secondary structural resonance in the operating frequency range. Actual frequency response values obtained by test are ±1 db, 7 to 2000 cps; ±3½ db, 5 to 5000 cps (bare table). Full ½" peak-to-peak displacement or 600 pounds force output is maintained at all frequencies, *without* power factor correction or use of changeable impedance matching taps.

A control console incorporates all operating controls, and associated monitoring and cycling equipment. Switch selected inputs consist of single frequency, sweep cycling or complex waveform signals. Special features include a dual beam 'scope for comparing input and Shaker table acceleration signals, and five adjustable circuits to compensate for decrease in transfer function (g output/volts input) as frequency increases.

Complete Engineering Data and Specifications on Request

THE CALIDYNE COMPANY

120 CROSS STREET, WINCHESTER, MASSACHUSETTS

SALES REPRESENTATIVES:

WALTHAM, MASS. Robert A. Waters, Inc. Waltham 5-6900
NEW HAVEN, CONN. Robert A. Waters, Inc. Fulton 7-6760
NEW YORK CITY AREA G. C. Engel & Associates Rector 2-0091
RIDGEWOOD, NEW JERSEY G. C. Engel & Associates Gilbert 4-0878
PHILADELPHIA, PA. G. C. Engel Chestnut Hill 8-0892
NORTHERN NEW YORK Technical Instruments, Inc. Waltham, Mass. Waltham 5-8445
CLEVELAND, OHIO M. P. Odell Co. Prospect 1-6171
DAYTON, OHIO M. P. Odell Co. Oregon 4441
DETROIT, MICHIGAN M. P. Odell Co. Superior 8-5114
WASHINGTON, D. C. F. R. Jodon, Inc. Hobart 2-4300
SOUTHEAST W. A. Brown & Assoc. Alexandria, Va. Overlook 3-6100
CHICAGO, ILLINOIS Hugh Marsland & Co. Ambassador 2-1555
INDIANAPOLIS, INDIANA Hugh Marsland & Co. Glendale 3803
MINNEAPOLIS, MINN. Hugh Marsland & Co. Colfax 7949
DALLAS, TEXAS John A. Green Co. Fleetwood 7-7385
HOLLYWOOD, CALIFORNIA G. S. Miller Co. Hollywood 2-1195
SAN FRANCISCO, CALIF. G. S. Miller Co. Lytell 3-3438
ALBUQUERQUE, NEW MEXICO G. S. Miller Co. Albuquerque 5-8606
SEATTLE, WASH. G. S. Miller Co. Lander 3320
CANADA Measurement Engineering Ltd. Arnprior, Ont., Phone 400 Toronto, Ont., Mayfair 8860
EXPORT Rocke International Corp. 13 East 40th St., N. Y. 16, N. Y. Murray Hill 9-0200

Mechanical

Where moderate speed range is required and where machine may be stopped to make speed changes. Horsepower range—1½ to 300. Speed adjustment range—9 to 28 percent. Two *Vari-Pitch* sheaves used together double range of adjustment.

Combination starter

Squirrel-cage motor

Vari-Pitch stationary control drive

Mechanical

Where infrequent change of speed in low horsepower drives is required and machine may be stopped for speed adjustment. Especially suitable for fan drives, stokers, small pumps and tools. Horsepower range—fractional to 4 hp. Speed adjustment range—18 to 50 percent. Use of two adjustable sheaves doubles speed adjustment range.

Across-the-line starter

Squirrel-cage motor

Texrope adjustable drive

EIGHT WAYS TO GET VARIABLE SPEED

Electrical

Where stepped speed control is satisfactory. Available with stepless control in larger sizes by using liquid rheostat. Speed is varied by means of control on secondary windings of motor. Horsepower range—5 hp and up. Speed adjustment range—50 percent of synchronous speed to full load speed.

Wound-rotor motor control

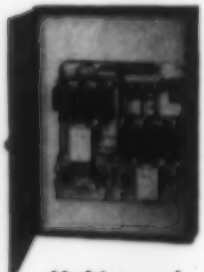
Wound-rotor motor

Texrope V-belt drive

Electrical

Where a few definite speeds are required. Up to four speeds available from one motor. Motor is built on standard squirrel-cage frame with special windings and control. Furnished for variable torque, constant torque and constant horsepower. Horsepower range—½ hp up.

Texrope and *Vari-Pitch* are Allis-Chalmers trademarks.



Multi-speed motor starter

Multi-speed squirrel-cage motor

Texrope V-belt drive

Write for Engineering Literature

AC ALLIS-CHALMERS

ALLIS-

Mechanical

Where speed must be changed while machine is in motion. Particularly good for machines requiring fine adjustment while operating. Double range of adjustment may be obtained by using two *Vari-Pitch* sheaves. Horsepower range—1½ to 600. Speed adjustment range—9 to 28 percent with one *Vari-Pitch* sheave.

Reduced voltage starter | Squirrel-cage motor | *Vari-Pitch* motion control drive

Mechanical

Where very wide range speed control is required or where enclosed unit is desired. May be manually or remotely controlled. Motor may be mounted on speed changer housing for compact installation. Horsepower range—1½ to 75. Speed adjustment range—3¼ to 1.

Across-the-line starter | Squirrel-cage motor | *Vari-Pitch* speed changer

COMPLETE DRIVES from One Reliable Source

Electrical

Where great versatility is required. Speed may be varied by various types of control, either stepped or stepless. For both constant and variable torque loads. Horsepower range—½ hp up. Speed adjustment range—zero to maximum speed. Maximum speed in smaller sizes, 3500 rpm.

Direct current control | Direct current motor | *Texrope* V-belt drive

Combination

Where extremely wide range is required, a combination drive adds the speed control range of the motor to that of the *Vari-Pitch* drive. Hundreds of combinations of any of the above units can be worked out to fit the requirements of a particular design.

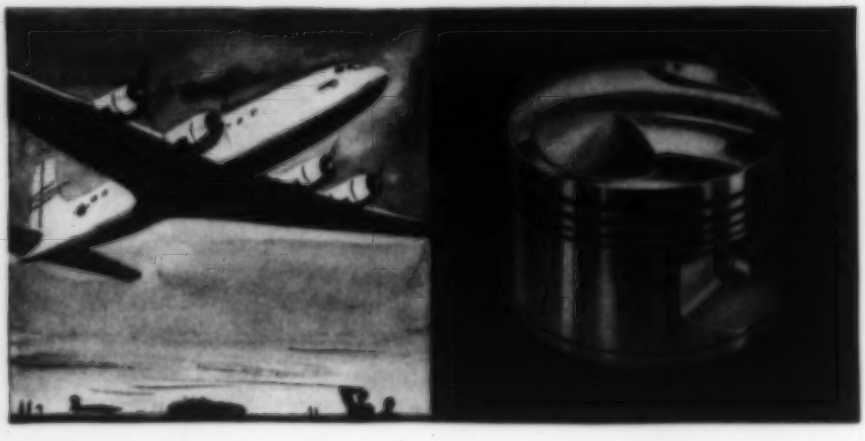
Wound-rotor motor control | Wound-rotor motor | *Vari-Pitch* motion control drive

A4523

CHALMERS

Milwaukee 1, Wisconsin

Ice Scoops and Aircraft Pistons



Thompson Precision-Engineers Light Metal Castings for All Industry

YES, there *is* a connection—both ice scoops and aircraft pistons are products of Thompson's versatile Light Metals Division.

Ice scoops, used in making cold soft drinks, and pistons, used in high speed aircraft engines are but two of the many light, strong, durable castings being designed, developed and produced by Thompson's exacting engineers.

Over 50 years experience in research and manufacture of precision metal parts enables Thompson today to offer aid to all forms of industry. Thompson is now producing light metal castings for such diversified products as aircraft and washing machines; buses and garbage disposers; tractors and outboard motors; automobiles and industrial engines.

Regardless of your product, if you use castings, Thompson's creative engineers will gladly show you where and how you can simplify your operations and save on costs with Thompson Light Metals Castings.

For a detailed description of the Thompson Light Metals facilities which are available to you, send for your free copy of "Creative Castings." Just write to Dept. M-4. Light Metals Division, Thompson Products, Inc., 2269 Ashland Rd., Cleveland 3, Ohio.

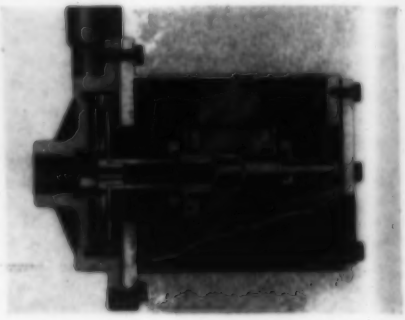
You can count on

Thompson Products

LIGHT METALS DIVISION
2269 Ashland Rd. • Cleveland 3, Ohio

New Parts

(*Continued from Page 273*)



with titanium, zirconium, Hastelloy, Monel and Carptenter 20 stainless, as well as other corrosion-resistant alloys. Made by **Chempump Corp.**, Station H, 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Circle No. 95, Page 347, for more data

Preload Indicator 96

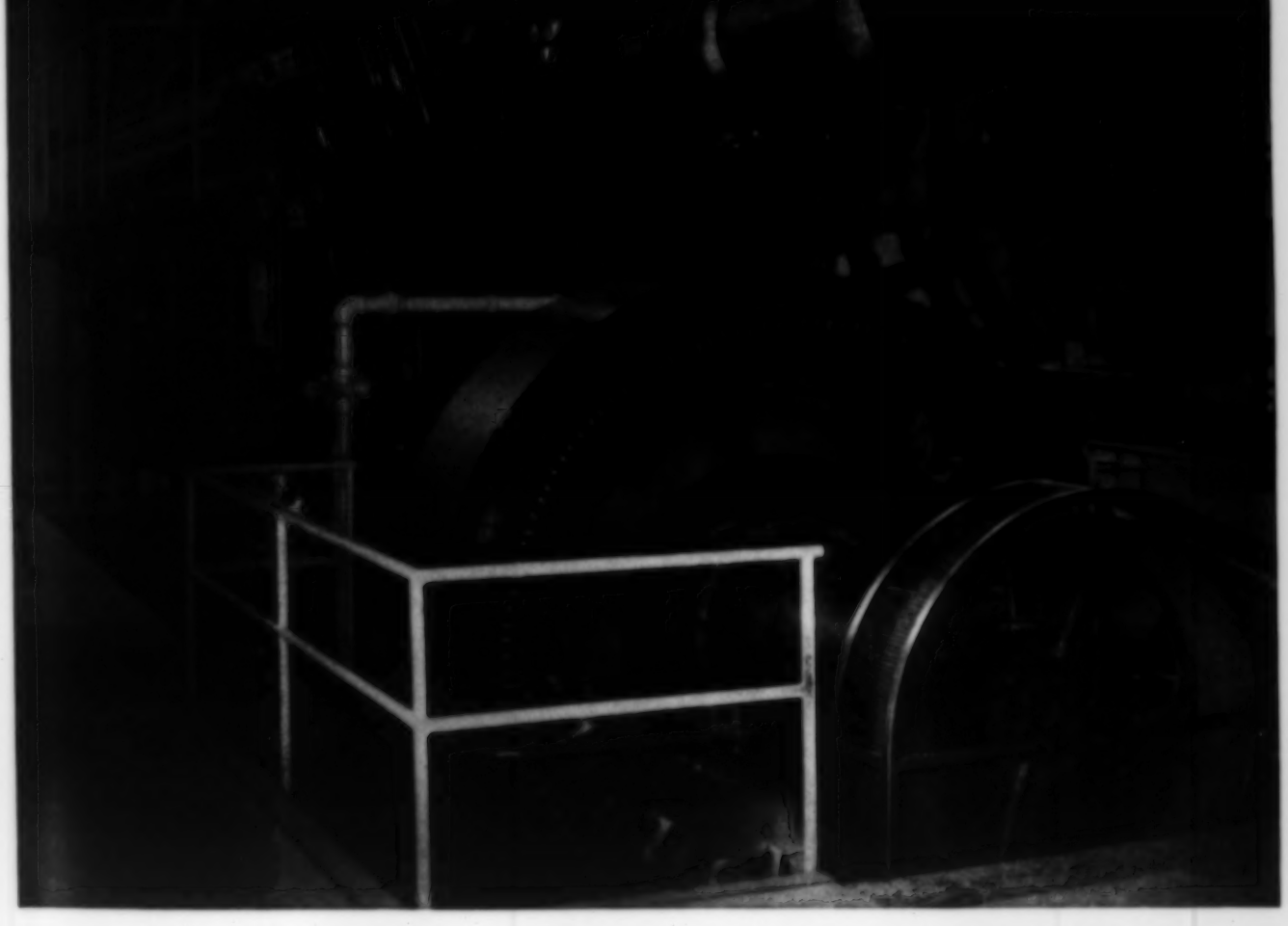
permits tightening bolts to high preload strength

The PLI washer, a preload indicating device, provides a means for tightening bolts to predetermined preloads as high as 80 per cent of bolt yield strength. The washer is composed of two concentric steel rings, one of which fits freely inside the other. The inner ring is higher than the outer ring, and a

predetermined load is required to compress it to the height of the outer ring. The washer, which becomes an integral part of a nut and bolt assembly, can be used at either end of the connection. In use, it is sandwiched between two high-strength washers and placed under the head of the bolt or under the nut. As the bolt is tightened, the inner ring takes the load and is first elastically and then plastically compressed. This washer tech-

2 ROSS EXCHANGERS

keep this Cooper-Bessemer Engine running at correct temperature



To meet the need for additional generating capacity, this big 16-cylinder Cooper-Bessemer dual-fuel engine was installed in the municipal power plant at Princeton, Illinois.

Furnished with it were two Ross Exchangers: One cools lube oil. The other cools jacket water. *Engine temperatures never exceed desired operating levels!*

Almost everywhere that diesel, gas or gasoline engines go, Ross Exchangers also go. Specified by users as well as engine builders, they are regularly selected for numerous types of prime equipment to cool air, oil, water and hydraulic fluid.

Such acceptance is the combined result of many factors: Thermal efficiency . . . Ruggedness . . . Compactness . . . and Standardization that makes a broad range of sizes promptly available . . . Plus, of course, cooperative Kewanee-Ross engineering service.

For more information, request Bulletins 1.1K5 and 2.1K5.

KEWANEE-ROSS CORPORATION

DIVISION OF AMERICAN RADIATOR & STANDARD SANITARY CORPORATION

1429 WEST AVENUE • BUFFALO 13, N. Y.

In Canada: Kewanee-Ross of Canada Limited, Toronto 5, Ont.

Serving home and industry: AMERICAN-STANDARD • AMERICAN BLOWER • CHURCH SEATS & WALL TILE • DETROIT CONTROLS • KEWANEE BOILERS • ROSS EXCHANGERS • SUNBEAM AIR CONDITIONERS

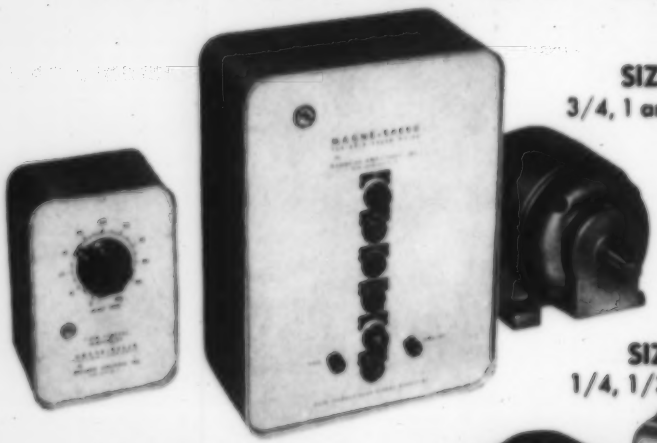
AFFILIATE OF GENERAL CERAMICS CORPORATION

Magnetic Amplifiers · INC

—announces its new

VARIABLE SPEED DRIVE

MAGNE-SPEED*



SIZE II —
3/4, 1 and 1-1/2 HP

SIZE I —
1/4, 1/3 and 1/2 HP

Stepless, instant starting, compact, 50:1 speed range, good regulation without tachometer, long life, virtually maintenance free service, low cost, fast response, reversibility, dynamic brake, local or remote control. Write for Bulletin S580-5-55.

Other MA Products and Services

Magnetic Servo Amplifiers
Transi-Mag * Amplifiers
Analog Computers
Photoelectric Controls
DC and AC Regulated Power Supplies

* Trade Name

Application engineering and conversion of tool machines and production processes to automatic control.

Magnetic Amplifiers • Inc
Tel. CYpress 2-6610 • 632 TINTON AVE., NEW YORK 55, N. Y.

New Parts

nique is accurate to within ±10 per cent of the predetermined preload. Cadmium-plated and heat-treated alloy steel washers are available for standard bolt sizes ranging from No. 10 to 1½ in. diameter. Smaller sizes will be made. Washers are available for a wide variety of bolts, ranging in ultimate tensile strengths from 80,000 to 240,000 psi. Made by **Standard Pressed Steel Co.**, Jenkintown, Pa.

Circle No. 96, Page 347, for more data

Hydraulic O-Rings 97

for temperature range from −65 to 275 F

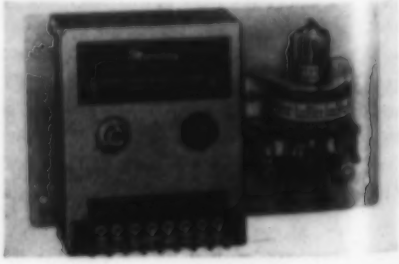
O-rings made from synthetic rubber compound No. 47-671 are suitable for aircraft hydraulic service. They can be used in the temperature range of −65 to 275 F and meet functional and physical requirements of MIL-P-18017 specifications. Made by **Parker Appliance Co.**, Rubber Products Div., 17325 Euclid Ave., Cleveland 12, O.

Circle No. 97, Page 347, for more data

Sensitive Relay 98

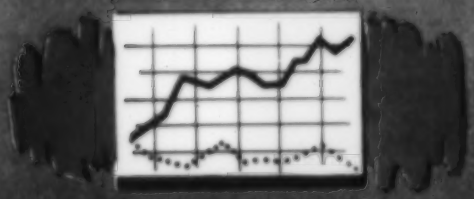
controls up to 60-amp loads

Low current devices or circuits such as a photocell will activate this electronic mercury-plunger Micrelay, designed for control of high-power, high-current loads up to 60 amp, or 3 hp at 115 v ac. It is also available for control of loads up to 35 amp, or 2 hp at 115 v ac, for either normally open or normally closed operation. Mercury-to-mercury action is enclosed in hermetically sealed tube, affording safe operation even in explosive atmospheres. Closure time is 35 milliseconds. Relay supplies its own operating voltages for high and low impedance applications and is suitable for control circuit



PRODUCT SALEABILITY IS A BASIC REQUIREMENT OF SUCCESSFUL DESIGN

Resistance welding can lower your cost of fabrication

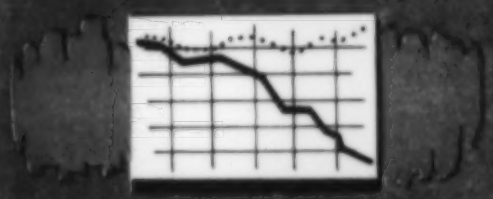


INCREASES PRODUCTION

Why take the time to drill a hole and then fill it with a bolt or rivet? The utter simplicity of Sciaky resistance welding reduces multi-step fastening operations to just one! Actually, it's quicker to make a spot weld than to drill the hole. (Often less time even than punching the hole!) Automatic welder operation and feeding allows greater production economy than any other method of fabrication.

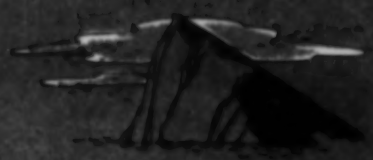
REDUCES LABOR DEMAND

The operation of a Sciaky welder is automatic. Control functions are preset and only one operator (not skilled) is required to produce consistent, high quality welds in high production. Ease of operation reduces operator fatigue and minimizes danger of human errors. Routine service, set-up and production control for a whole battery of Sciaky welders are readily handled by just one man.



LOWERS OPERATING COST

The production capability, the elimination of additional materials for fastening (rivets, bolts, nail, etc.), and the lack of expensive jigs and fixtures—these advantages explain the impressive operating economies of Sciaky resistance welding. Further, only one operator (not skilled) is required. Skilled workers and extra helpers are released for other operations.



DEPENDABLE AND CONSISTENT

Beyond structural integrity, the unusual dependability and consistency of Sciaky welder operation is the result of a refinement of mechanical design and electronic control. That is why Sciaky designs and builds electronic controls to satisfy each specific welder application. Mechanical functions are carefully considered, and components are designed by Sciaky for the same reason.

Greater Economy, Increased Production For Your Design

When Sciaky Patented Three-Phase Resistance Welding Is Specified!

LOWER INSTALLATION COSTS—Invented, patented and pioneered by Sciaky, the Three-Phase principle of welder operation offers direct savings . . . lower installation cost, smaller distribution lines, and smaller switch gear than conventional single phase . . . no need for extensive compensators or capacitors to improve welding conditions.

LOWER POWER BILLS—Sciaky balanced load Three-Phase with 85% power factor (compared to approximately 30% of conventional single phase), and 50% reduction in power demand, is far less expensive to operate than conventional single phase unbalanced load welders.

GREATER WELD CONSISTENCY—The equalizing current characteristics of Sciaky patented Three-Phase results in much greater weld consistency. Sciaky Three-Phase will maintain the weld quality at a given control setting throughout the longest production run.

MUCH LONGER ELECTRODE TIP LIFE—Sciaky patented Three-Phase with its characteristic progressive current rise and inherent lack of skin effect greatly extends electrode tip life. Electrodes have much longer life, and the need to stop production to dress them is far less frequent.

Regular issues of "Resistance Welding At Work," containing detailed examples of Sciaky resistance welding applications, are available to you. Read how other companies, large and small, have improved their product and lowered operating cost . . . impressive examples of Sciaky's basic thinking—welders designed to do *more work at lowest operating costs* with *maximum reliability!*

Largest Manufacturers of Resistance Welding Machines in the World

SCIAKY

Sciaky Bros., Inc., 4939 West 67th Street, Chicago 38, Ill., Portsmouth 7-5600

The day-in, day-out excellence, the quality which is standard in every Curtis Universal Joint, has made the Curtis Joint the quality standard of the industry.

Each Curtis Universal Joint component is made from specially selected steel, individually heat-treated for a specific purpose. This accounts for the long life and dependable performance of Curtis Universal Joints.

CURTIS UNIVERSAL JOINTS

- 14 sizes always in stock
- Fewer parts, simpler construction
- Complete equipment for government tests

Our catalog torque and load ratings are substantiated by constant tests. You can depend on them.

Not sold through distributors. Write direct for free engineering data and price list.

TRADE MARK **CURTIS**

UNIVERSAL JOINT CO., INC.

5 BIRNIE AVENUE, SPRINGFIELD, MASS.

As near to you as your telephone

A MANUFACTURER OF UNIVERSAL JOINTS SINCE 1919

impedances from 10 megohms to 100,000 ohms. Made by **Ebert Electronics Corp.**, 212-23I Jamaica Ave., Queens Village 28, N. Y.

Circle No. 98, Page 247, for more data

Mechanical Seal 99

for use on rotary shafts

BB-21A Mechanipak seal is designed for use on rotary shafts at pressures up to 150 psi. Standard construction includes brass shell

and brass washer. Buna-N or Neoprene bellows are provided for operating temperatures up to 212 F and pressures up to 150 psi. Silicone bellows are used in seals which operate at temperatures up to 400 F where pressure does not exceed 50 psi. Seals are available for shafts from ⅜ to 3 in. in diameter. Applications include use on rotary shafts of equipment such as centrifugal pumps, automatic dishwashing machines, commercial dishwashers, gear boxes, speed reducers and agitators. Made by **Garlock Packing Co.**, Palmyra, N. Y.

Circle No. 99, Page 247, for more data

Small Thermostat 100

for household and commercial appliances

Available in either direct or reverse-acting types, breaking or making contact on temperature rise, the EA thermostat is suitable for use in clothes driers, electric room heaters, unit air conditioners and other household and commercial appliances and equipment. This Underwriters' Laboratories - approved unit is less than 3 in. long and incorporates a snap-acting mechanism. Dials are available optionally in standard temperature ranges of 60 to 250, 100 to 200, 200 to 400 and 200 to 550 F, and with 1 to 10 reference points. Made

by **Robertshaw - Fulton Controls Co.**, Robertshaw Thermostat Div., Youngwood, Pa.

Circle No. 100, Page 247, for more data

Swivel Joints 101

in ½ and ¾-in. sizes

Two swivel joints made in ½ and ¾-in. sizes include one with permanent clamp design for use on air, fuel and hydraulic lines where free swiveling action is required,

and the controlled torque design shown. The permanent clamp type, Junior Joint No. 1, is designed to prevent hose kinking, while controlled torque model No. 2 permits quick positioning and locking of lines. Both are cast from Zamak No. 5, a corrosion resistant alloy with high impact strength. Synthetic O-rings in joints resist aromatic fluids, cutting and lubricating oils, soluble oils, gasoline, kerosene, diesel oils, water and air. Clamps are cadmium-plated steel. Made by **Chiksan Co.**, 330 N. Pomona Ave., Brea, Calif.

Circle No. 101, Page 247, for more data

Dual Switch 102

shifts two circuits at once

Consisting of two basic switching units operated by a single roller-lever actuator, the 6AS13 low-

40th YEAR NEWS

PARKER RUST PROOF COMPANY

PUBLISHED BY PARKER RUST PROOF COMPANY FOR THE METALWORKING INDUSTRY

On this, our Fortieth Anniversary, our humble and grateful thanks to those we have been privileged to serve during two World Wars, the Great Depression and now our period of greatest prosperity.

Parker Rust Proof Company,
R. W. Englehart, President

A LIST OF "FIRSTS" BY PARKER RUST PROOF

1. First commercial phosphate rust-proofing process (1915).
2. First high speed production phosphate rust-proofing process.
3. First process for spray application of phosphate coating materials.
4. First steel mill application for phosphate coating galvanized sheets.
5. First phosphate coating of ordnance items.
6. First substitute for tin in tin cans.
7. First phosphate coating process for wear resistance on machined elements.
8. First process for cold drawing seamless and welded carbon steel tubes.
9. First process for cold drawing stainless steel.
10. First process for cold extrusion of metal.
11. First process for treatment of metal to permit elimination of ground coat in porcelain enameling of metal (1955).

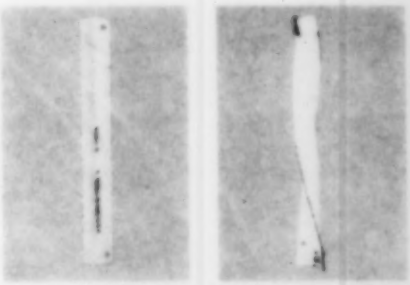
BIRTHDAY TWINS: NEW PRETREATMENT FOR PORCELAIN ENAMEL; BONDERITE WITH ICRA

Two new Parker products have been announced within a few months of the company's 40th Anniversary. One is a revolutionary new approach to porcelain enameling on ferrous metals, the other is a refinement in phosphate coating to produce more durable, more attractive paint finishes.

Parker Pre-Namel 410

This new Parker product, a pretreatment used to prepare ferrous metals for porcelain enameling, eliminates the need for a ground coat, makes it unnecessary to use premium alloys, permits application of finish coat directly on the metal.

One-coat porcelain enameling over Parker Pre-Namel 410 is simpler and more economical to produce. Durability of the finish is improved, too, as shown by standard ASTM and PEI tests. Rejects and parts for re-operation are reduced to a degree never before possible. 98% acceptance has been attained in production test runs. Plant men familiar with the product estimate that economies through Parker Pre-Namel 410 will amount to from 1 to 3 cents per square foot of enameled surface.

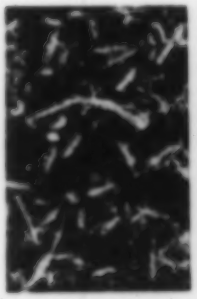


Left: Conventional two-coat porcelain enamel on enameling iron angle failed when twisted 70°. (Metal, twisted less than its elastic limit, returned to original shape.)
Right: Finish coat only, over Parker Pre-Namel 410 on enameling iron angle, withstood 240° twist before failure.

Parker Pre-Namel has been thoroughly tested for two years. It is ready now for use in production applications on the various types of articles finished with porcelain enamel.

New Bonderite Has Built-In Crystal Refining Agent

Series 800 Bonderites contain ICRA (Internal Crystal Refining Agent). This new built-in control produces a denser, finer, more uniform crystalline structure which results in improved paint adhesion and greater luster and reflectiveness.



Photomicrograph, 100X, of steel panel after phosphate treatment without ICRA. Note large crystals.

Photomicrograph, 100X, of steel panel after treatment with Bonderite with ICRA. Note fine, dense crystals.

This new series of Bonderites has the simplicity of operation and control, the uniformity of results and the over-all economy that characterizes all Parker products.

There's a formulation to meet almost every requirement of material to be treated, type of equipment and operating speed.

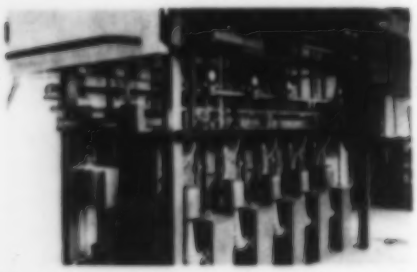
AUTOMATION IN FINISH SYSTEMS IN 1928

Automatic handling of materials through a series of operations—"automation"—is new in name only to Parker. Among the contributions of this company to the metalworking industry has been the development of straight line production, without intermediate handling, of parts through cleaning, metal preparation, dry-off and painting.

Parker's engineering department, working with conveyor and equipment companies, pioneered the first continuous dip-treatment installation in 1928, in which wheel rims were carried through cleaner, rinse and Parco Compound tanks by conveyor.

When faster-acting Bonderites were developed by Parker research, spray equipment was designed to accomodate the higher production speeds it made possible. The reduced costs and higher uniform quality, that comes with automatic operation, were made available to users of Parker Products years ahead of other automatic processing.

"GOLD STANDARD" IN PANELS FOR PAINT TESTS



This automatic machine treats panels with Bonderite on a production basis to meet the demands of Parker customers.

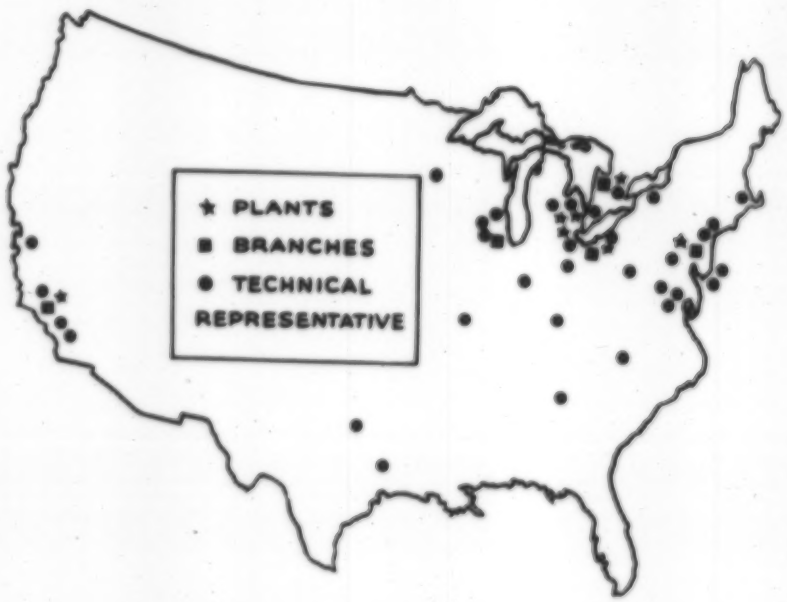
The Bonderite-treated panels prepared in Parker's service laboratories are the Gold Standard used in testing paint performance. To evaluate new paints and maintain quality control on production, manufacturers will use over one half million of these Bonderite-treated panels this year. When you use Bonderite in your plant, you are using the recognized leader in the field.

New Products, New Methods Come from Parker's Research Laboratories

There has been a research department at Parker for as long as there has been a company. In the early days it was a one- or two-man department. Now the technical staff numbers over 100. Parker research is responsible for the products and processes listed under "Parker Firsts" on the preceding page, and for hundreds of refinements and short-cuts that have meant money, time and material savings for plants throughout metalworking.

Parker's customers profit by having this imaginative, productive, and experienced research program working for them.

LOOK HOW CLOSE PARKER MEN AND PARKER PRODUCTS ARE TO YOU



Fast supply and service are important in the Parker package! The map shows coast-to-coast locations of plants, branch offices and technical representatives. No matter where you are, there's Parker service quickly available.

Parker technical representatives, backed by the most extensive know-how and experience in the industry, are themselves thoroughly experienced. The average Parker field representative has 11 years on the job!

WORLD-WIDE EXPERIENCE! Parker and its affiliates in Germany, England and France share over 125 years of experience in this specialized field.

For full information on any of the products listed below, call or write

PARKER RUST PROOF COMPANY, 2167 East Milwaukee, Detroit 11, Michigan

***Bonderite**
corrosion resistant paint base

***Parco Compound**
rust resistant

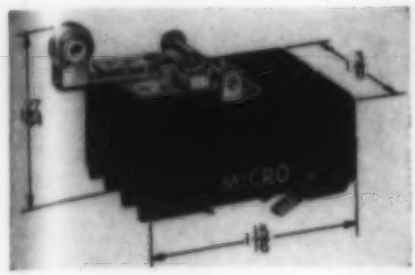
Bonderite and *Bonderlube
aids in cold forming of metals

***Parco Lubrite**
wear resistant for friction surfaces

***Parker Pre-Namel**
pretreatment for porcelain enameling

Tropical Paints
maintenance paints for industry since 1883

**Reg. U.S. Pat. Off.*



force, double-pole switch can shift two isolated circuits at the same time. Operating point of one unit is adjustable to provide either simultaneous actuation or a definite sequence of operation. The switch is available with a variety of lever lengths, either straight or formed, and with or without a roller. Basic switch units are listed at 15 amp at 125, 250 or 460 v ac; ½-amp at 125 v dc; and ¼ amp at 250 v dc. Higher electrical capacity units can be used. Made by **Minneapolis-Honeywell Regulator Co.**, Micro Switch Div., Freeport, Ill.

Circle No. 102, Page 247, for more data

Friction Clutch 103

provides high torque capacity in relation to size

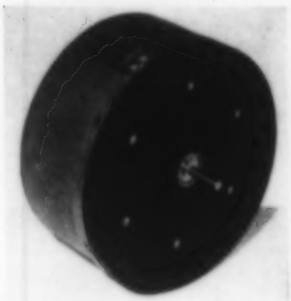
This friction clutch is suitable for applications where high speeds prohibit the use of jaw clutches and where smooth and gradual pickup is required. Over-the-center toggle mechanism assures positive positioning and minimizes the possibility of accidental engagements or disengagements. It also allows drag-free idling. Large friction areas provide high torque capacity in relation to size. Heat dissipation is high, because the friction surfaces are directly cooled by air. A split friction plate permits inspection without removal of the clutch from the shaft. Clutches have capacities up to 170 hp at speeds ranging from 10 to 1800 rpm. Three types are offered: with a sleeve for mounting sprockets, gears, pulleys or other power transmission equipment; with a ring for bolting drums, sprockets, pulleys or sleeves directly to the gear ring of the clutch; and with a friction clutch coupling for use in connecting two in-line shafts. **Link-Belt Co.**, 307 N. Michigan Ave., Chicago 1, Ill.

Circle No. 103, Page 247, for more data

Potentiometer 104

is highly accurate

Model MP-10 potentiometer is a comparison standard rotation-to-voltage transducer for basic measurement, potentiometer testing and calibration, and analog multiplication. It operates with linearities to 0.002-per cent and is not susceptible to torque overloads or burnout. A Teflon shaft seal and high-leakage construction prevent internal loading. Resistance range is 5 to 200 K ohm; standard resistance tolerance is 5 per cent. Temperature coefficient of resistance is ±20 ppm per deg C. Rotation is ten turns, with 90-deg electrical and mechanical overtravel at each end. The unit is rustproof and resistant to fungus growth. Made by **Analogue Controls Inc.**, 37 W. 20th St., New York 10, N. Y.



Circle No. 104, Page 247, for more data

Terminal Blocks 105

assembled with 1 to 24 sections per block

Rated at 300 v, 25 amp, type MA and MAT terminal blocks consist of separate molded Bakelite terminal sections held in place within a

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50th Anniversary Member A.G.M.A.

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*S. H. Pooley
Belting Co.
F. E. Allen Co.
*Chicago, Illinois
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Schrade-Batterson Co.
*Cincinnati 14, Ohio
Metzger Machine Co.
*Cleveland, Ohio
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Ohio Gear Co.
*Detroit 3, Michigan
Abrasive & Supply
Murray Equip. Co., Inc.
*Erie, Pa.
Cohen-Industrial
Supply
*Grand Rapids 2, Mich.
F. Raniville Co.
*Hagerstown, Md.
Hagerstown Equip.
Houston 3, Texas
Behring's Bearing
Service, Inc.
*Indianapolis 2, Indiana
A. R. Young Co., Inc.
Kalamazoo, Michigan
Bard Steel & Mill
Supply Co.
*N. Kansas City 16, Mo.
Sesco Engineering &
Supply Corp.
*Los Angeles 1, Calif.
J. W. Minder Chain
& Gear Co.
*Louisville 2, Kentucky
Alfred Halliday
*Massillon, Ohio
Hdwe. & Supply Co.
*Memphis 2, Tennessee
Memphis Bearing &
Supply Co.
Milwaukee 11, Wisc.
Albert F. Korf Co.
*Minneapolis 4, Minn.
Ind. Supply Co., Inc.
*New Orleans, La.
*(Gears) R. J.
Tricon Co., Inc.
*(Reducers) Woodward
Wight & Co., Inc.
*New York, N. Y.
*(Reducers) Patron
Transmission Co., Inc.
*(Gears) Atlantic
Trans. & Gear Sales
*Oakland, California
Adam Hill Co.
*Philadelphia, Pa.
*Robert L. Latimer Co.
*Rothman Belting &
Equipment Co.
*Piqua, Ohio
Bornell Supply Co.
*Pittsburgh 30, Pa.
Standard Machinists
Supply Co.
*Plainville, Conn.
Abel Trans. Co.
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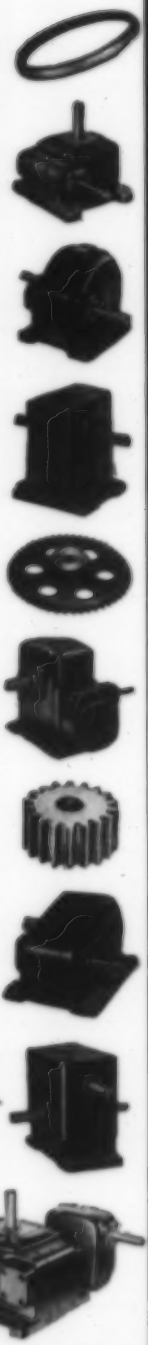
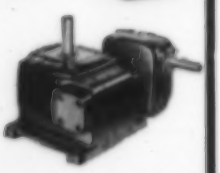
*Toledo 12, Ohio
G. & J. Bearings &
Supply Co.
*Trenton, New Jersey
Wiley-Hughes Co., Inc.
*Tucson, Arizona
Tucson Bearing Co., Inc.

IN CANADA, *Montreal, Quebec, John Braid-wood & Sons, Ltd. *Stocks carried.



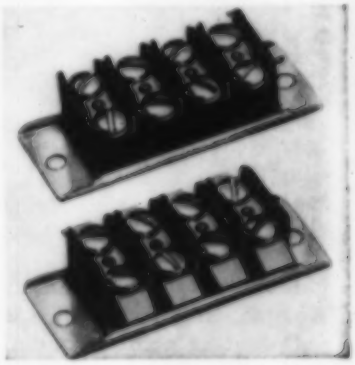
ESTABLISHED 1915

OHIO GEARS



OHIO GEAR CO. • 1338 E. 179th ST. • CLEVELAND 10, OHIO

New Parts



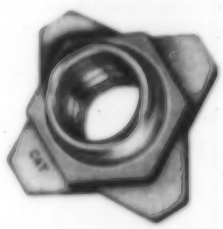
plated steel channel. Spacing of terminals is ½-in. center-to-center. A full ⅜-in. creepage distance is provided between terminals and ground. Units can be factory assembled with from 1 to 24 terminals per block. Made by **Curtis Development & Mfg. Co.**, 3250 N. 33rd St., Milwaukee 16, Wis.

Circle No. 105, Page 247, for more data

Lug Nut Union 106

has four lugs

Made in 2 to 4-in. sizes, the 4-Star hammer type lug nut union combines both lug and hexagonal shaped nuts with regular or Double-Start Acme threads. Fast



make or break is accomplished with either a hammer or a wrench. The nut unions are forged from solid steel bars, conforming to ASTM specification A-105, grade 2. Made by **Catawissa Valve & Fittings Co.**, Catawissa, Pa.

Circle No. 106, Page 247, for more data

Fan Duty Motors 107

rated ¾ to 20 hp

Double-width prelubricated sealed ball bearings, integrally cast fins for heat dissipation and windings with thick Formvar insulation are incorporated in type EFD totally-enclosed fan duty motors. Made

Drawer liners for **Sears, Roebuck and Co.** "Caravan" furniture are produced by *Panelyte Division*, **St. Regis Paper Co.**, Chicago 41, Ill.

Vacuum-formed impact styrene trays... big selling point at low cost

Here's a design idea that's helping to sell Sears' "Caravan" furniture—drawer liners vacuum-formed from extruded sheets of BAKELITE Brand High-Impact Styrene.

Easy cleaning makes them a hit—notice the rounded corners. The housewife merely wipes these trays clean, though they can readily be removed and washed without harm. Their smooth surfaces don't snag fabrics. Their color complements the natural wood of the drawers.

These sales advantages are inexpensive, too, because vacuum-forming is a fast, economical production method. And BAKELITE High-Impact Styrene TGD-5001 was developed especially for vacuum-forming. Since sheets of TGD-5001 are still glossy after forming, no extra finishing operations are needed. TGD-5001 offers a range of attractive colors, and demonstrates excellent toughness in service.

Learn more about BAKELITE High-Impact Styrenes for extrusion and vacuum-forming. Write today to Department KW-103.

BAKELITE
BRAND
High-Impact Styrenes

Visit BAKELITE's exhibit, Booth 1375, National Metal Exposition, Oct. 17-21, Philadelphia Convention Halls, Philadelphia, Pa.

BAKELITE COMPANY, *A Division of Union Carbide and Carbon Corporation* UCC 30 East 42nd Street, New York 17, N. Y.

In Canada: Bakelite Company, Division of Union Carbide Canada Limited, Belleville, Ontario

The term BAKELITE and the Trefoil Symbol are registered trade-marks of UCC

Announcing ADJUSTABLE-STROKE Air-Clamp CYLINDERS

Actual overall length of horizontal models, including ram extension, 3½", 5", 6".

"More per hour, with Mead Air Power"

Now—put pressure where it's wanted instantly and cheaply—with Mead's powerful new midget air cylinders (1" bore, single-acting, spring return.) Stroke is adjustable. Use 'em singly or in groups to move, hold, press or eject small work pieces; to close and open large jigs, forms, fixtures. They'll replace human fingers and mechanical clamps in countless routine jobs.

These new Midget Air Clamp cylinders bear the new Mead label of Guaranteed Quality. Each is guaranteed to give you millions of trouble-free cycles—to be a better value, dollar for dollar, than any comparable cylinder. Try them!

*TRADE MARK

Actual overall height of vertical models, including ram extension, $3\frac{3}{32}$", $4\frac{25}{32}$" and $5\frac{25}{32}$".

PATHFINDER IN AIR POWER AUTOMATION

—SAVES TIME!

These six brand-new Air Clamp cylinders with adjustable strokes variable from ½" to 3" can be put to work where longer strokes are needed and stroke can be "tuned" to exact length wanted even *after* setup is made! This feature alone multiples their usefulness, saves hours of time designing, laying out special jigs, fixtures.

—SAVES AIR!

Stroke change quickly made with spanner wrench (included with cylinder). You can conserve air in large fixtures (where dozens or hundreds of Midget Air Clamp cylinders are used) by using "just enough-no more" stroke. The shorter the stroke, the faster the cycle.

—SAVE SPACE & MONEY!

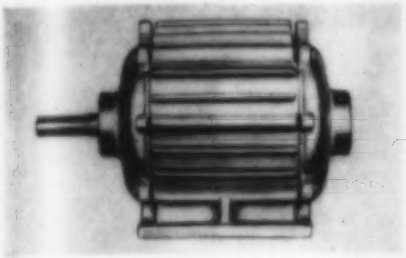
You can shorten stroke to the minimum to save space in cramped quarters. The cylinder "nose" telescopes into barrel reducing stroke and overall length. All this at prices so low you can almost *forget* their modest first-cost. But you'll *remember* the countless man-hours saved—the lessened fatigue of your workers at monotonous jobs—the improved quality and accuracy of their work!

Write Factory or Nearest Mead Representative For Bulletin MD-105

(See Alphabetical Index of Thomas' Register for address, phone number.)

Midget Air Clamps are a Quality-Guaranteed product of

MEAD SPECIALTIES COMPANY



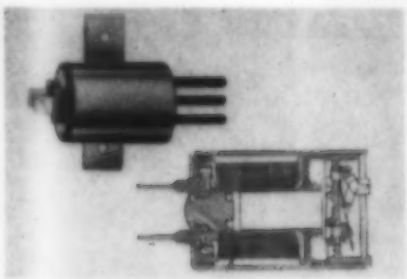
in ratings of ¾ to 20 hp, they are available with optional connection boxes to fit any air-over-motor application. Type EXFD explosion-proof motor is usable where volatile gases and explosive dusts are prevalent. Made by **Lima Electric Motor Co.**, 117 Findlay Rd., Lima, O.

Circle No. 107, Page 247, for more data

Appliance Relay 108

sealed against moisture and dust

This compact relay is completely enclosed in a metal case, which is plugged with molded Bakelite on the contact end. Three contact leads are equipped with female AMP terminals; the coil has two male AMP terminals. Relays are



available for operation on either ac or dc, from 6 to 115 v. Contacts are rated up to 8 amp at 115 v, noninductive. Contact arrangement is single-pole, double-break. Size of the relay is 2 11/32 x 1 7/32 x 1 7/32 in. Made by **Guardian Electric Mfg. Co.**, 1621 W. Walnut St., Chicago 12, Ill.

Circle No. 108, Page 247, for more data

Electronic Timer 109

has 2 per cent accuracy

Full scale ranges of 0.2, 0.5, 1.5, 3, 6, 12, 24 or 60 seconds are available in model 2, type CK electronic timer. A variable control permits

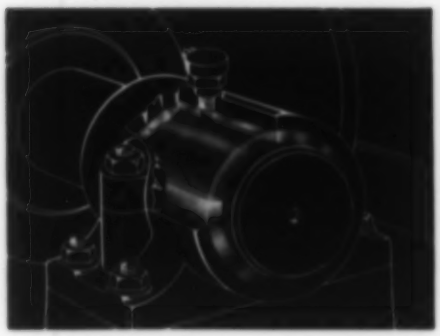
(*Continued on Page* 290)

BUNTING BEARINGS

GIVE YOU

Competitive Advantages

Employment of an unnecessarily expensive bearing for the "prestige" it gives your product sometimes proves to be more of a handicap than an aid to sales. It increases cost, price and service expense. It often puts the sales emphasis on somebody else's "prestige" instead of your own. The sturdy, simple, inexpensive Cast Bronze Bunting Bearing will give you maximum bearing performance at minimum bearing cost and permit you to sell your product on its own merits at a profitable low price.



Why not re-examine your present designs. There is a Bunting engineer near you who can give you helpful technical counsel. Or write our Product Engineering Department at Toledo.

Bunting®

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BRANCHES IN PRINCIPAL CITIES • DISTRIBUTORS EVERYWHERE

at no extra cost to you . . .

NEW Quality Features on All AIR and HYDRAULIC CYLINDERS

Miller

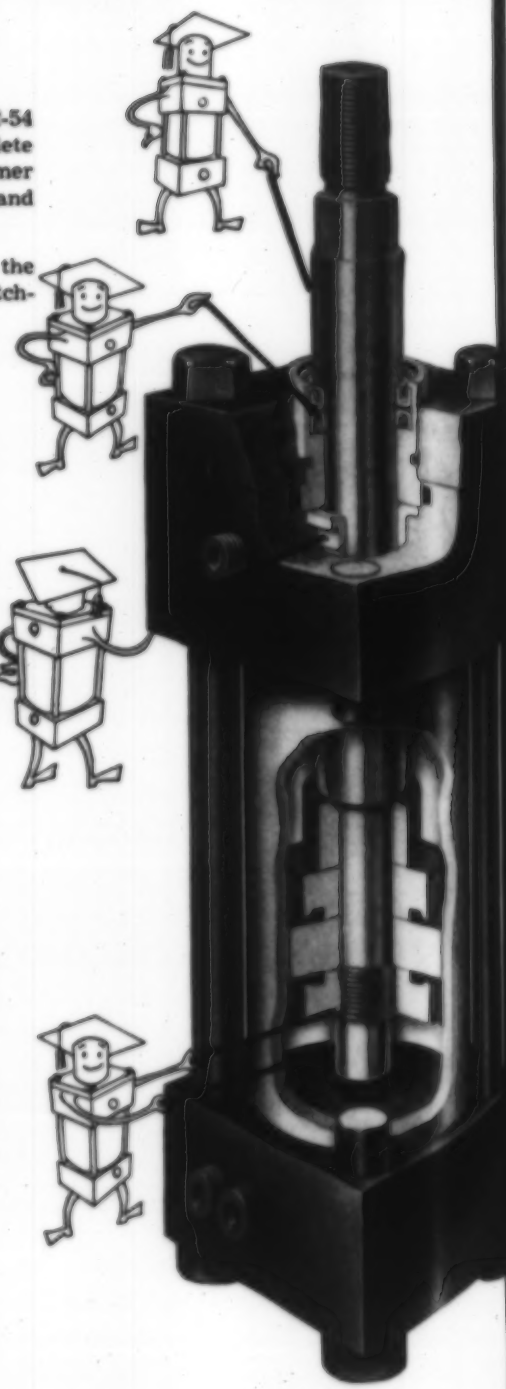
CASE HARDENED CHROME PLATED PISTON RODS

On all Miller Air and Hydraulic Cylinders

Benefits To You

CASE-HARDENED Piston Rods (52-54 Rockwell "C") provide practically complete protection against damage from hammer blows, wrench-dropping, mishandling, and similar occurrences.

The HARD CHROME PLATING over the case-hardened rods protects against scratch-damage and rust.



"TEFLON" WIPERS

On all Miller Air and Hydraulic Cylinders

Benefits To You

"TEFLON" Rod Wipers and "TEFLON" Hydraulic Seals withstand temperatures from —100° F. up to 500° F. They are impervious to practically all known chemicals, including the fire-resistant, special, and standard hydraulic fluids in current use.

"TEFLON" HYDRAULIC ROD SEALS

On all Miller Hydraulic Cylinders only

RUST RESISTANT SURFACE

On all Miller Air and Hydraulic Cylinders

Benefits To You

Highest quality Black Ferric Oxide Finish provides rust protection in air cylinder operation and on all cylinders during shipping and installation.

Cylinder heads, caps, mountings, pistons, followers, and the unplated portions of the piston rods have this finish. It is not recommended for water service.

WRITE FOR CYLINDER BULLETINS H-104 and A-105

Complete Miller cylinder line includes: air cylinders, 1½" to 20" bores, 200 PSI operation; low pressure hydraulic cylinders, 1½" to 6" bores for 500 PSI operation, 8" to 14" bores for 250 PSI; high pressure hydraulic cylinders, 1½" to 12" bores, 2000-3000 PSI operation. All mounting styles available.

Over 8,000 Different Cylinder Selections Available for Immediate Delivery. Write for Complete List.

EFFECTIVE DATES

These new Miller features will be provided at no extra cost after January 1, 1956—and at Miller's option prior to that date.

SALES AND SERVICE FROM COAST TO COAST

CLEVELAND • YOUNGSTOWN • DAYTON • TOLEDO • CINCINNATI • COLUMBUS
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Miller

MILLER FLUID POWER CO.

2006 N. Hawthorne Ave., Melrose Park, Ill.

AIR & HYDRAULIC CYLINDERS • BOOSTERS • ACCUMULATORS
COUNTERBALANCE CYLINDERS

(Advertisement)

Four More Miller Firsts . . .

Our "Report To Cylinder Users" was a simple statement of Miller Fluid Power Company's policy. In it was mentioned our dedication to the constant improvement of our products.

In line with this policy, here are new quality cylinder features that will eliminate many of the problems which you have reported to us.

Miller gave cylinder users one of its firsts when we chrome-plated all cylinder piston rods. Our reason was obvious. Chrome-plating gave every rod a mirror-like finish that no corrosive or abrasive dust could scratch. Miller made this chrome-plated, longer lasting rod standard. AT NO EXTRA COST.

Preventing Damage To Piston Rods

There were still plenty of hazards to which piston rods were subjected. A careless workman with a too handy wrench or pair of pliers meant a scored piston rod. A falling object striking the rod dented the softer metal beneath the plating of chrome. A jolt during assembly left its trouble-breeding mark. All of these nicked and scored the piston rods, damaging the whole assembly. Little could be done about this beyond repair and replacement—until the Miller announcement that from now on the piston rods on all cylinders—air and hydraulic—will be specially hardened (52-55 Rockwell C) to foil the carelessly used tool, the accident in transit or assembly, the falling object or unnoticed knock. Naturally, the new hardened rods will still be chrome-plated. Miller will now make this super quality an everyday standard. AT NO EXTRA COST.

Meeting The Challenge Of The New Demands On Seals

Rod seals on Miller hydraulic cylinders were constructed to be leakproof under all ordinary operating conditions. We guaranteed this. But we also stated in all our catalogues that for special conditions there must be special rod seals at an extra cost. Rod seals to withstand high temperatures had to be specially constructed. Where fire resistant fluids were used, special rod seals had to be provided at an extra cost. Because many fire resistant fluids destroy ordinary packing.

The present widespread use of these fluids and excessive heat generation from high speed operation and increased loads have resulted in reports of trouble on cylinders where ordinary seals were subjected to these hazards. These reports were not received with joy at Miller, even when the fault was definitely not ours. We don't like to have trouble develop on any Miller installation under any condition. So we decided to do something about these problems of the rod seals.

A new expensive material known as "TEFLON" has been developed for use as seals. This material is impervious to temperatures from —100° to plus 500° F. It resists all known fluids, even the most destructive of the fire resistant fluids. Now, every piston rod on every Miller hydraulic cylinder will be fitted with "TEFLON" Piston Rod Seals. AT NO EXTRA COST.

In addition, all rod wiper seals on all Miller Air and Hydraulic cylinders will be of the same chemical-and-heat resisting Teflon material.

These Teflon rod wiper seals will be standard on every Miller cylinder, regardless of how and where it will be used. This is Miller's way of doubly insuring cylinder users against all possible hazards. AT NO EXTRA COST.

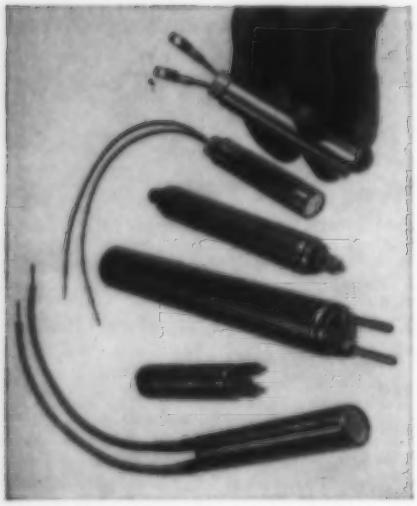
Protection Against Rust

The barrels of Miller air cylinders are of moisture-resistant brass. The barrels of hydraulic cylinders, since they run in oil, are protected once they are installed and in operation. Beyond this all cylinder parts are subject to rust and corrosion. Such exposed parts as heads, caps and tie rods quickly show the unsightly evidences of rust. At least this has been so up till now. But all this is now being corrected.

From now on Miller will protect all these parts on both air and hydraulic cylinders with a black oxide process in which a chemically created ferric oxide coating is developed on the surface of the metal to protect against rust and other corrosion. Every Miller cylinder sold will carry this added protection. AT NO EXTRA COST.

These four new Miller firsts are added to the many firsts established by Miller. Like other Miller firsts which created new departures in cylinder design and construction, these are now offered as Miller standard specifications. AT NO EXTRA COST.

MILLER FLUID POWER COMPANY
2006 N. Hawthorne Avenue
Melrose Park Illinois



improve your spot heating

• increase production • reduce costs

CHROMALOX

Electric Cartridge Heaters

When used to apply concentrated heat in confined work areas that require close thermal control, Chromalox Electric Cartridge Heaters are modern, highly efficient production tools.

New design improvements provide even longer life and higher heats. Uniform diameter assures even heating with no hot spots. Designed for operating temperatures up to 1000°F.

Versatile Chromalox Electric Cartridge Heaters are used in dies, platens, molds, sealing and cutting knives, processing machinery . . . wherever heat is needed inside equipment.

Let the Chromalox Sales Engineering staff solve your heating problems . . . electrically.

Write for your copy of Catalog 50

Contains helpful information on design, uses, and prices of complete line of Chromalox Electric heaters, elements, thermostats, contactors and switches.

To get some interesting facts about additional applications of electric heat, ask for Booklet F1550 — "101 Ways to Apply Electric Heat."

Edwin L. Wiegand Company

7575 Thomas Boulevard, Pittsburgh 8, Pennsylvania

EDWIN L. WIEGAND COMPANY
7575 Thomas Boulevard, Pittsburgh 8, Pa.
I would like to have—

☐ a copy of Catalog 50
☐ a copy of "101 Ways"
☐ a Sales-Engineer contact me

Name_____
Company_____
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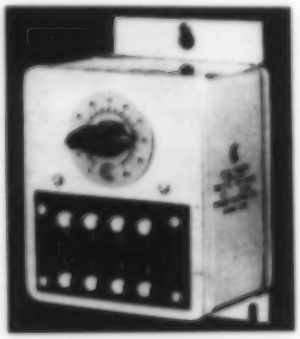
City_____ Zone____ State_____

A-4456A

setting intervals down to 0.03-second for each range. Timer operates by means of a cold-cathode tube, requiring no warmup time. Relay contacts are rated 8 amp



noninductive at 115 v ac. Because of built-in voltage regulator, timed interval varies less than 2 per cent of full-scale for any line-voltage change between 95 and 125 v. Available for front or back-of-panel mounting, the timer has a dustproof housing and plug-in relays for easy servicing. Six operating styles are available, all of which measure 5 x 4¼ x 3 3/16 in. Made by **Farmer Electric Products Co.**, 21 Mossfield Rd., Waban 68, Mass.

Circle No. 109, Page 247, for more data

Metallic O-Rings 110

can be made square-shaped

These metallic O-rings for static sealing applications have straight sides of varying lengths and specified radii at the corners. Proper metal or finish plating can be specified for sealing against corrosive liquids and gases at high or low temperatures and pressures. Illustrated are three square types compared with an 8-in. diameter round

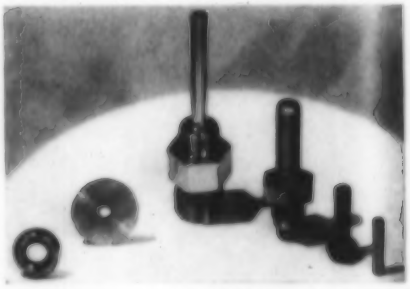
ring. They are made from 321 stainless tubing with 3/16-in. cross section and 0.020-in. wall thickness. Largest ring measures 46½ x 55½ in. Triangular and other configurations are possible. Made by **United Aircraft Products Inc.**, 1116 Bolander Ave., Dayton, O.

Circle No. 110, Page 247, for more data

Temperature Probes 111

have high output

When used with TME bridge network, these high-resistance temperature probes provide 5-v output signal without amplification for as little as 150-deg F temperature change. Varied configurations



are available for measuring fluid, surface, structure, air, hydraulic line, cylinder head and subminiature component temperatures. Made by **Arnoux Corp.**, Dept. MD-4, P. O. Box 34628, Los Angeles 34, Calif.

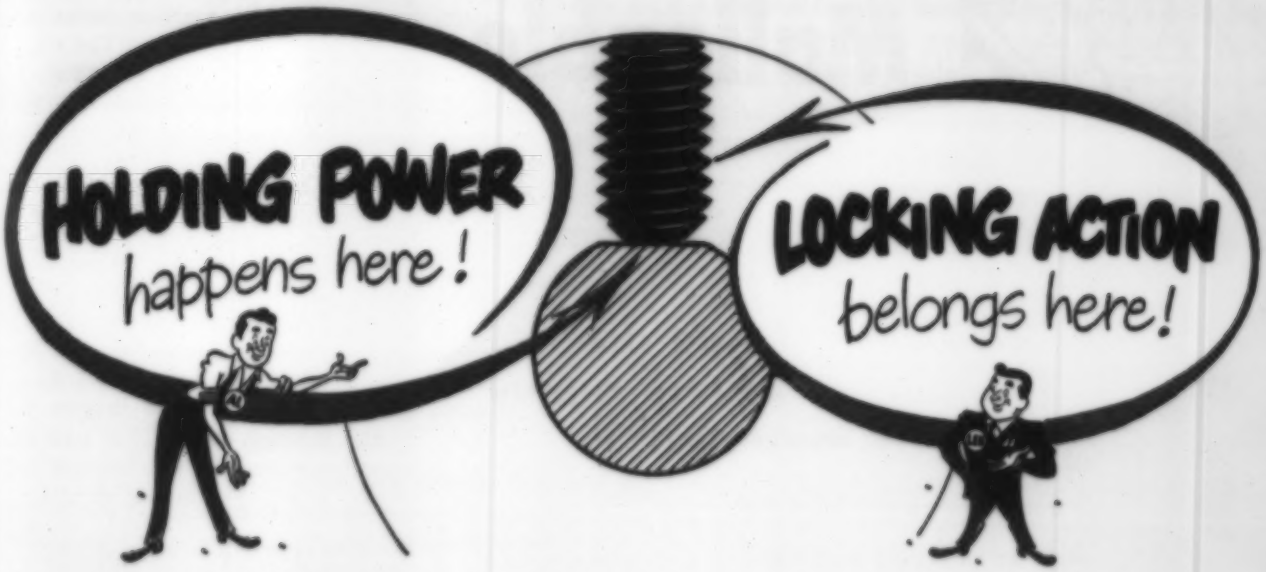
Circle No. 111, Page 247, for more data

Ceramic Coating 112

twice as hard as tool steel

Super refractory Flame Rock hard aluminum oxide coating is applied by a spray type operation. Ceramic powders are melted in a flame directed at the object to be coated. Approximately twice as hard as tool steel, this coating has a melting point above 3600 F and provides excellent electrical and thermal insulation. It is unaffected by most corrosive agents, including many molten metals. It resists chipping, even under direct impact. Slightly porous, it retains lubricants. The coating can be applied to various metallic and nonmetallic materials, including steel, titanium, carbon, aluminum, magnesium, brass, copper and glass. Applica-

SPECIFY ALLENPOINT SET SCREWS BECAUSE



For maximum *holding power* against both rotation and sideway motion Allen developed the new *Allenpoint* — proved superior in exhaustive impartial tests (data on request).

Allen ○ screws do not weaken the holding power of the point with serrations in an attempt to make it perform a locking function too. High, uniform accuracy of fit, pitch diameter and perfect thread lead provide locking action the *right* way — from maximum thread contact. This locks the screw in place perfectly during use and *re-use* under extreme vibrating stress.

Your Allen Distributor's full stock of Allenoy and stainless socket screws puts an Allen warehouse right in your area. Allen-trained representatives plus Allen factory engineering bring a world of precision fastening experience as near as the phone on your desk.

FREE —

New and improved pocket SCREW CALCULATOR. Write to Dept. G for it on your business letterhead.

How about Malleable ?

...Don't overlook the advantages of this highly versatile material!

STANDARD malleable iron is a strong cast ferrous alloy having a remarkable combination of properties:

- Toughness and ductility
- Excellent machinability
- High impact resistance
- Resists corrosion

...and how about Pearlitic Malleable?

PEARLITIC malleable iron is a special type of malleable having these unique characteristics:

- Exceptional bearing properties
- Easily machined
- High yield strength—45,000 to 80,000 psi.
- Can be selectively hardened

It's easy to design for simplicity and good appearance in malleable iron—helps you cut costs on current production. Consult your nearest malleable foundry or write to the Malleable Founders' Society for further information.

1800 Union Commerce Building — Cleveland 14, Ohio

New Parts

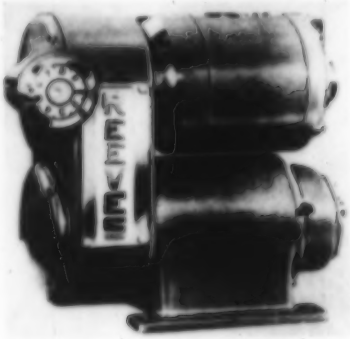
tions include pump linings, automobile cylinder linings, jet engine and rocket parts, bearing surfaces, aircraft wheel and brake assemblies, washing machine parts, valve seats and metal rolls. The powder is nontoxic and noncombustible. Made by **Montaine Corp.**, 7127 S. Chicago Ave., Chicago 19, Ill.

Circle No. 112, Page 247, for more data

Adjustable-Speed Drive 113

is motorized 1-hp packaged unit

Compact and applicable to all industrial equipment, No. 100 Vari-Speed Motodrive is rated 1 hp and is available in speed ranges from 2:1 through 8:1. This packaged unit combines a "weatherized" motor, a speed-changing mechanism



and a heat-treated helical gear speed reducer. Any one of 112 different assemblies can be furnished to meet space requirements. Spiral-groove lubrication is provided on all sliding surfaces. The All-Position handwheel shown is standard, but mechanical, automatic and electric remote controls are available. Made by **Reeves Pulley Co.**, 1277 Seventh Ave., Columbus, Ind.

Circle No. 113, Page 247, for more data

Magnetic Clutch 114

for computers and miniature servo systems

Developed as a component for precise applications in guided missiles, computers and miniature servo systems, model T507-1 miniature

Make your own comparison of the

Gilmer THE ORIGINAL "TIMING" BELT DRIVE

versus other forms of Power Transmission

	GILMER "TIMING" BELT DRIVE	FLAT BELTS	CHAIN	V BELTS	GEARS
1. Can it transmit 1/100 to 300 HP without slippage . . . and without lubrication?	Yes	—	—	—	—
2. Does it eliminate noise and vibration caused by metal-to-metal contact?	Yes	—	—	—	—
3. Does it operate at maximum efficiency, indefinitely, without take-up?	Yes	—	—	—	
4. Does it make possible very compact, short-center drives of ratios up to 15-to-1?	Yes	—	—	—	
5. Does it eliminate need for initial tension, permitting all the drive's tension to be used effectively . . . and reducing bearing wear?	Yes	—	—	—	
6. Can it operate satisfactorily at peripheral speeds above 12,000 FPM?	Yes	—	—	—	
7. Does it maintain constant angular velocity?	Yes	—	—	—	
8. Is its weight very low in proportion to its strength?	Yes	—	—	—	
9. Does it make possible precise "timing", without appreciable backlash, between two or more widely separated shafts?	Yes	—	—	—	
10. Does it eliminate the expense and added weight of lubricants, lubricating devices and covers?	Yes	—	—	—	
11. Does it save so much power as to sometimes permit use of lower-powered motors?	Yes	—	—	—	
12. Does it have unusually long, maintenance-free service life?	Yes	—	—	—	

WHEN PLANNING A DRIVE, CONSIDER ALL FIVE!

NEOPRENE-ENCASED, CABLED STEEL WIRE GIVES THE BELT GREAT STRENGTH WITHOUT BULK

Naturally, these questions are phrased to emphasize the unique *combinations* of features provided by the "Timing" Belt drive. Question 1, for example, might have been divided into two separate questions. But this would not point up the important fact that the "Timing" Belt drive is the *only positive drive requiring no lubrication.*

Certainly, the four older types of drives will always have their special places in the power transmission picture. The important fact is that the design engineer now has at his disposal a *fifth* type of drive ideally suited to so many applications that more than a million are now in use.

Write for your copy of the Gilmer "Timing" Belt Stock Drives Manual, to Gilmer "Timing" Belt Division at the address below.

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NEW YORK BELTING & PACKING CO. 1 Market St., Passaic, N. J.

America's Oldest Manufacturer of Industrial Rubber Products

YOU insure

RUGGED FIELD PERFORMANCE
plus PRODUCTION SAVINGS

when you specify these

JOHN CRANE MECHANICAL SEALS

"JOHN CRANE" Types 1 and 2 shaft seals come pre-assembled. They are quickly and easily installed. Tolerances need not be critical due to the self-adjusting seal head. This is accomplished through special construction of the synthetic rubber bellows head. Moving freely under spring and hydraulic pressure, it automatically compensates for shaft end play, as well as washer wear.

Sealing faces are precision-lapped to prevent stuffing box leakage. No break-in runs necessary. Positive drive feature eliminates all stress on bellows. This feature also permits the use of light spring load to minimize wear on sealing faces. Seal needs no attention over long periods of operation.

Recommended for water, oil and other services non-injurious to synthetic rubber. Pressures to 200 psi. Temperatures: –40° to +212°F.

Type 1. For stuffing boxes of limited diameter.

Type 2. For stuffing boxes of limited length.

Above seals also available in balanced construction (1-B, 2-B) for pressures up to 500 psi.

Write for Bulletin S-213-1

Crane Packing Co., 1825 Cuyler Avenue, Chicago 13, Illinois.
In Canada: Crane Packing Co., Ltd., 617 Parkdale Ave., N. Hamilton, Ont.

JOHN CRANE CRANE PACKING COMPANY

New Parts

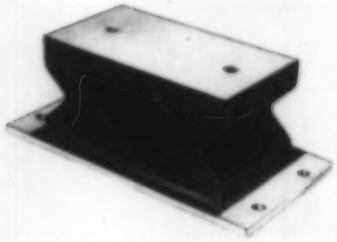
magnetic clutch has excellent torque characteristics and high speed engagement and disengagement times. Single-ended concentric input and output shafts permit mounting gearing at one end. Made by **Sterling Precision Instrument Corp.**, Instrument Div., 34-17 Lawrence St., Flushing 54, N. Y.

Circle No. 114, Page 247, for more data

Machinery Mount 115

employs rubber member to damp vibration

Rubber lattice members of this machine and equipment mount provide a high degree of vibration and noise isolation, particularly in the low - frequency high - amplitude range. It is available with capacities of 250 to 3000 lb, with static deflections of ¼ to 1½ in. The rubber section is bonded to



steel plates at the top and bottom. Damping characteristic of the elastomer stops excursion of machinery when passing through resonance in starting or stopping. Shock load is carried by the rubber in shear to provide a high degree of horizontal stability. Made by **Lord Mfg. Co.**, 1635 W. 12th St., Erie, Pa.

Circle No. 115, Page 247, for more data

Feed Rate Control 116

operates with extreme accuracy

A self-contained hydraulic resistance unit, the model DCP-50A Hydro-Check controls movement precisely to maintain a preset feed rate. Changes in temperature, load and air line pressure do not affect its operation. Developed for use with Bellows air motors in applications where extreme accuracy of movement is required, the control incorporates automatic flow and thermal compensation. A liquid-

filled metallic bellows constantly corrects the flow control valve in accordance with changes in oil temperature. An upstream flow control regulator compensates for variations in load and fluctuations in air line pressure. Minute residual air bubbles in the fluid are broken by a sintered metal filter. Adjustable feed-rate control is possible, ranging from zero to the normal velocity of the controlled machine element. This Hydro-Check is available in standard stroke lengths of 2, 4, 6, 9, 12, 15 or 18 in. Control can be on either forward or retract stroke, or both. Made by **Bellows Co.**, 230 W. Market St., Akron 9, O.

Circle No. 116, Page. 247, for more data

Counting Tube 117

has 12 cathodes

Dekatron model GS12D cold-cathode counting tube has 12 cathodes individually connected to pins on the base. The tube has a 13-pin base, plus two extra flying leads. Envelope design provides a short

tube with a smooth end face to facilitate readability. Count is determined by noting the position of the glow on one of the 12 radially spaced cathodes around the central anode. The particular cathode that glows is positive with respect to the others. Thus a positive voltage is available at any selected count. Counting rate is from 0 to 4000 pulses per second. Maximum

(*Continued on Page* 300)

RESEARCH AT WORK FOR YOU

CHIEF SANDUSKY

FERROUS AND NON-FERROUS CENTRIFUGALLY CAST ROLLS, SLEEVES, TUBES, LINERS, CHUTES, RETORTS, RINGS, BUSHINGS, BEARINGS, ETC.

Many concerns are discovering strong, uniform, closely grained Sandusky centrifugal castings are essential to applications requiring maximum strength and extreme resistance to heat, corrosion, and abrasion. Chief Sandusky continuous research is ever expanding the range of these uses.

This versatility and quality results from constant research and testing in our modern firm and independent laboratories. Vast foundry and field experience also assists in supplying the proper castings for you.

Excellent machining facilities for drilling, turning and boring are available.

Call or write Sandusky, the leading source of ferrous and non-ferrous centrifugal castings. ALWAYS SPECIFY CHIEF SANDUSKY.

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Chief SANDUSKY CENTRIFUGAL CASTINGS

FERROUS AND NON-FERROUS

SANDUSKY FOUNDRY AND MACHINE CO., Sandusky, Ohio

BIG GRAMIX PARTS mean bigger savings for you . . .

New possibilities are now open to you through use of large GRAMIX parts. On our big new fully automatic presses we are now producing GRAMIX sintered metal parts much larger than before, and if you need parts of the size shown on the opposite page, it will pay you to consider re-designing around GRAMIX. GRAMIX parts are die-formed at high compacting pressures, thereby saving you a great deal of time machining holes or slots or teeth or keyways . . . these are built right into the die. Because they require little or no machining, GRAMIX parts eliminate scrap loss, and in production quantities the metal saved often offsets the cost of the dies. Parts can be produced from GRAMIX in fairly complicated shapes to tolerances as fine as .0005". They cost less and perform better than similar machined parts, and can be oil-impregnated to provide self-lubrication. Investigate the possibilities of these new big GRAMIX parts . . . write us for full details.

THE UNITED STATES

GRAMIX

1. Bronze Current Collector Shoe
2. Iron Pump Gear
3. Flanged Bronze Bushing
4. Iron Shifter Fork Lever
5. Bronze Pump Rotor
6. Nickel Silver Thrust Washer
7. Bronze Self Aligning Bearing

Parts approximately ½ actual size

GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW, MICHIGAN

TO MAKE IT SELL FASTER...

consider a ball

Again and again, the buying public has demonstrated—with cash on the line—that it has a strong and ready preference for *any* product that features one or more balls in its mechanism. Ball-point pens, for example . . .

So doesn't it seem like just good business to design a product with the "popular appeal" of a ball to help it *sell faster!*

A *Universal* Ball?

A Universal Ball so amazingly accurate (better than ten-millionths of an inch) that it opens up new and limitless possibilities of application for designers and manufacturers in *every* field . . . A ball so tiny you can scarcely see it (comes in many sizes you *can* see, too) . . . A ball that runs one of the toughest quality control "courses" you'll find anywhere.

We *like* to help people sell products as fast as they can make 'em. May we help you?

Universal Ball co.

WILLOW GROVE
MONTGOMERY CO., PA.

New Parts

(Continued from Page 297)

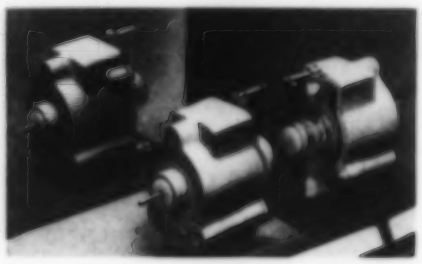
total anode current is 0.35 ma, and maximum voltage between electrodes other than the anode is 140 v. Minimum supply voltage, anode to cathode, is 350 v. The tube is 3.49 in. long, with a bulb diameter of 1.3 in. and a base diameter of 1.39 in. Made by **Atomic Instrument Co.**, 84 Massachusetts Ave., Cambridge 39, Mass.

Circle No. 117, Page 247, for more data

Miniature DC Motor 118

has self-governed, controlled speed

Measuring 1⅝ x 1¾ x 1⅛ in., this self-governed, controlled speed, dc electric motor weighs less than 3 oz. Its speed of 1800 rpm can be regulated within 1 per cent



from idling to full load over a range of battery voltages from 6.4 to 4.6 v. Motor has a three-pole armature, permanent magnet field, die cast zinc body and an armature mounted in self-aligning 1/16-in. diameter lifetime lubricated bearings. Applications of this low current drain motor include portable tape and wire recorders, movie cameras, timers and instruments. Made by **Kinder Co.**, P. O. 686, South Milwaukee, Wis.

Circle No. 118, Page 247, for more data

Potentiometers 119

available in ganged control units

Subminiature, wire-wound No. 500 Acepot potentiometers are made in ganged control units offering high precision and accuracy. Ganged units are available in the resistance range from 200 to 100,000 ohms. Standard accuracy of linear units is ±0.3-per cent independent linearity. Standard torque of the ½-in. diameter potentiometer is 0.035-oz-in. at 20 C; models with lower

LOVEJOY

Variable SPEED PULLEYS

SELECT-O-SPEED TRANSMISSIONS *Save You Money*

HERE'S WHY:

- ECONOMICAL IN COST compared to other variable speed transmission equipment. Simple in design but rugged in construction to give you long dependable service.
- EASILY INSTALLED on new or old equipment. Just as easy to operate. Finger-tip adjustment gives the right speed instantly.
- MAINTENANCE IS NEGLIGIBLE. No complicated mechanisms to get out of order. All parts can be readily inspected. Belts can be quickly adjusted or replaced.

Lovejoy Variable Speed Pulleys

are available in a complete range of sizes from fractional to 15 hp., ratios to 3 to 1.

Shown is a typical Lovejoy countershaft unit controlling speed of automatic spring coiler.

Lovejoy Select-O-Speed Transmissions

can be supplied with hand wheel or lever control. Fractional to 5 hp., ratios to 10 to 1.

This Lovejoy Select-O-Speed is used to control the speed of a printing press.

For your variable speed application, there is a type and size Lovejoy unit that will give you initial economy, dependable performance and long service life.

GET FULL DETAILS NOW!

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Mfrs. of Flexible Couplings, Variable Speed Pulleys and Transmissions, Motor Bases and Universal Joints.

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How to make standard units do special filtering jobs

Today's close mechanical tolerances and high standards of product purity have compelled engineers to adopt filtration as a basic design tool. Problem is — where and when can you save time, money and headaches by specifying standard off-the-shelf units to fit widely diversified applications?

To meet this situation, Purolator engineers have assembled the filter information designers most often need. So, if filtration is a factor in the equipment you're designing, let Purolator, most experienced filter manufacturer in the country, give you technical help in picking a standard unit for the job.

PUROLATOR

"FIRST in the field of filtering"

MAIL COUPON FOR DESIGN INFORMATION

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Dept. D5-108, Rahway, New Jersey

Please send me the following filter information

- ☐ Industrial Filter Catalog
- ☐ Filters for the Aircraft Industry
- ☐ Here is a schematic drawing and details of our problem. What would you suggest?

Name _____ Title _____

Company _____

Address _____

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Users prefer

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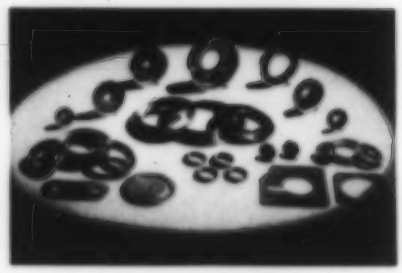
Garlock CHEVRON* Packing • At every pressure, from the lowest to the highest, this popular packing provides a positive, low friction seal. Ideally suited for use on hydraulic cylinders (both single and double acting), hydraulic rams, plungers of pumps and other reciprocating rods.

Garlock CHEVRON Packing

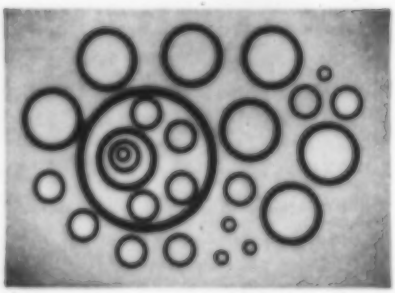
Garlock Leather Packings • Cups, "U" packings, "V" packings, washers, gaskets, discs and flange or hat packings, are available for all types of hydraulic service. Specify Garlock BITAN*, a chrome-and-oak-tanned leather, or THIOTAN* a synthetic rubber impregnated leather.



Garlock Leather Packings

Garlock O-Rings • Made to Garlock's rigid quality standards, these O-Rings are manufactured with precise tolerances, a flash-free finish, and utmost uniformity. 70 durometer rubber O-Rings in all popular sizes are available from any of Garlock's branch warehouses.

Call your Garlock representative or write for information on hydraulic packings, designating for which type, or types, you desire literature.



Garlock O-Rings

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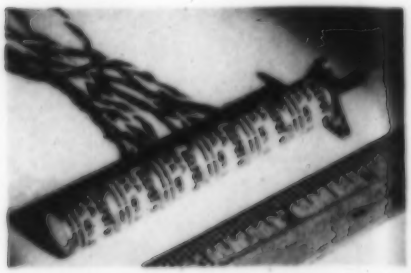
GARLOCK

PACKINGS, GASKETS, OIL SEALS,

MECHANICAL SEALS, RUBBER EXPANSION JOINTS

New Parts



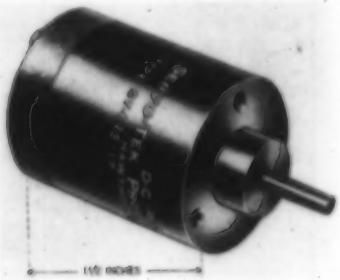
torque requirements are available. The potentiometers can be supplied sealed, except for the shaft, permitting potting along with their associated circuitry. Made by **Ace Electronics Associates,** 125 Rogers Ave., Somerville 44, Mass.

Circle No. 119, Page 247, for more data

Miniature Motors 120

permanent-magnet type operate on direct current

Available with a range of operating voltages from 6 to 80 v dc, with no-load speeds from 3000 to 20,000 rpm and power output up to 1/70-hp, these permanent-magnet motors are usable in servo mechanisms, instruments and other devices. Design incorporates ball



bearings, anodized finish, rotatable brush holder and flat, wafer type commutator. Housings are machined from solid aluminum. Motors are 1½ in. long and weigh 3 oz. Made by **Servo-Tek Products Co. Inc.,** 1086 Goffle Rd., Hawthorne, N. J.

Circle No. 120, Page 247, for more data

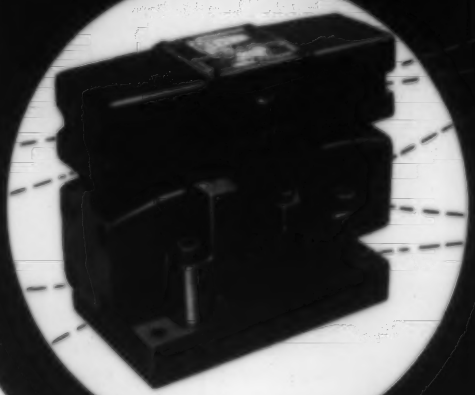
Restrictor Valves 121

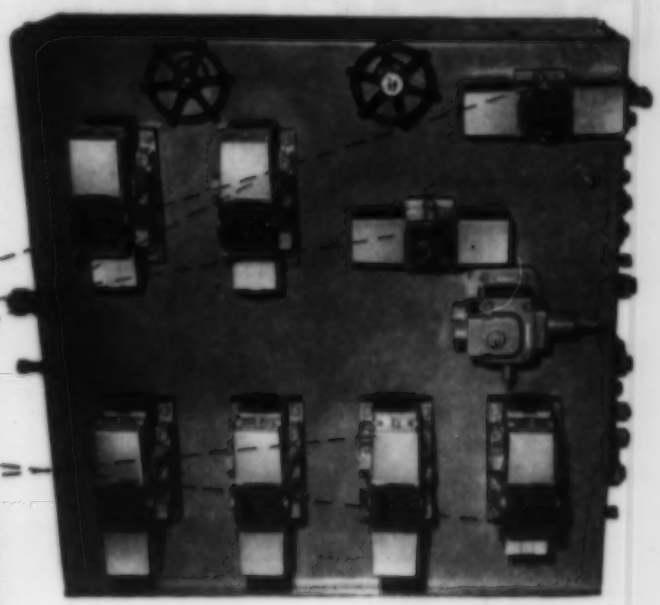
for 3000-psi hydraulic service

Available in either fixed one or two-way types with either internal or external threaded ends, series 1100 restrictor valves are designed for 3000-psi hydraulic service. They are made with aluminum, stainless or alloy bodies in ¼, ⅜

13 cylinder circuit controlled automatically

with Rivett Panel Valves





Integrated control panel with Rivett single and double solenoid pilot-operated valves; and double solenoid pilot valves.

These features offer better automatic control

1. 3000 P.S.I. conservatively rated.
2. Meet all J.I.C. Standards.
3. Greater flow capacity (¾" rated at 28 G.P.M. at 15 ft. per sec.)
4. 7 spool designs. All interchangeable in same body.
5. Dust-sealed, Moisture-resistant cover.
6. Shock-resistant spool
7. Shock-mounted, continuous duty solenoids.

Intricate circuit of new plastic injection molding machine contains 2 injection cylinders, an ejector cylinder, gate cylinder, metering cylinder, 2 die cylinders, 2 post cylinders, 2 plate cylinders and 2 shot cylinders—hydraulically controlled by 7 Rivett Panel Mounted Solenoid Operated Valves.

The Michigan manufacturer of this unit selected Rivett Valves for their: 1—greater flow capacity; 2—low pressure drop; 3—compactness; 4—shock resistance and 5—reduced maintenance.

Increasing numbers are finding Rivett 6600 Series Valves the most practical for control of automatic operations. Working with Rivett engineers and sales representatives, these users are able to improve a machine's design, operation, life, and above all to lower its cost!

RIVETT LATHE & GRINDER, INC.
Dept. MD-10 Brighton 35, Boston, Massachusetts

Get Data-filled Valve Catalog. Shows flow for all piston designs; working drawings; specifications. Write for free copy today!

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send us your telephone number ...it may mean a better future for you!

Because of increased emphasis on some of our long-range projects, we want to establish immediate contact with competent designers.

To those who qualify, we can offer a real opportunity to build solid, well-rewarded careers.

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Particularly important is your telephone number. We may want to call you at once to arrange for personal interviews or plant visits.

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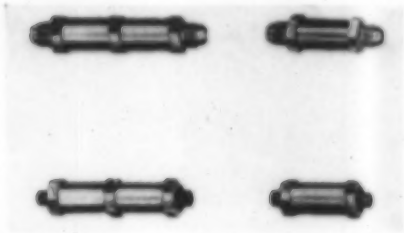
New Parts



and ½-in. tube sizes. They operate in ambient temperature range of −65 to 275 F. One-way type meters in the restricted flow direction and permits full line flow in the free-flow direction. The two-way model meters in both directions of flow. Made by **Aircraft Products Co.**, 300 Church Rd., Bridgeport, Pa.

Circle No. 121, Page 247, for more data

Repeat Cycle Timer 122

operates on low power

Providing two adjustable timed intervals in sequence, model No. 4 repeat cycle timer utilizes an electronic circuit with two cold-cathode triodes. Operation is continuous with application of power. No warm-up is required and no filament power is consumed. Independent adjustability of both on and

off cycles from 0.1 to 12 seconds is provided. Output is a single-pole, double-throw relay with 5-amp contacts. The only moving part is an electromagnetic relay. Timer is available for panel mounting or in a 3 x 4 x 5-in. box. Made by **G. C. Wilson & Co.**, 1915 Eighth Ave., Huntington, W. Va.

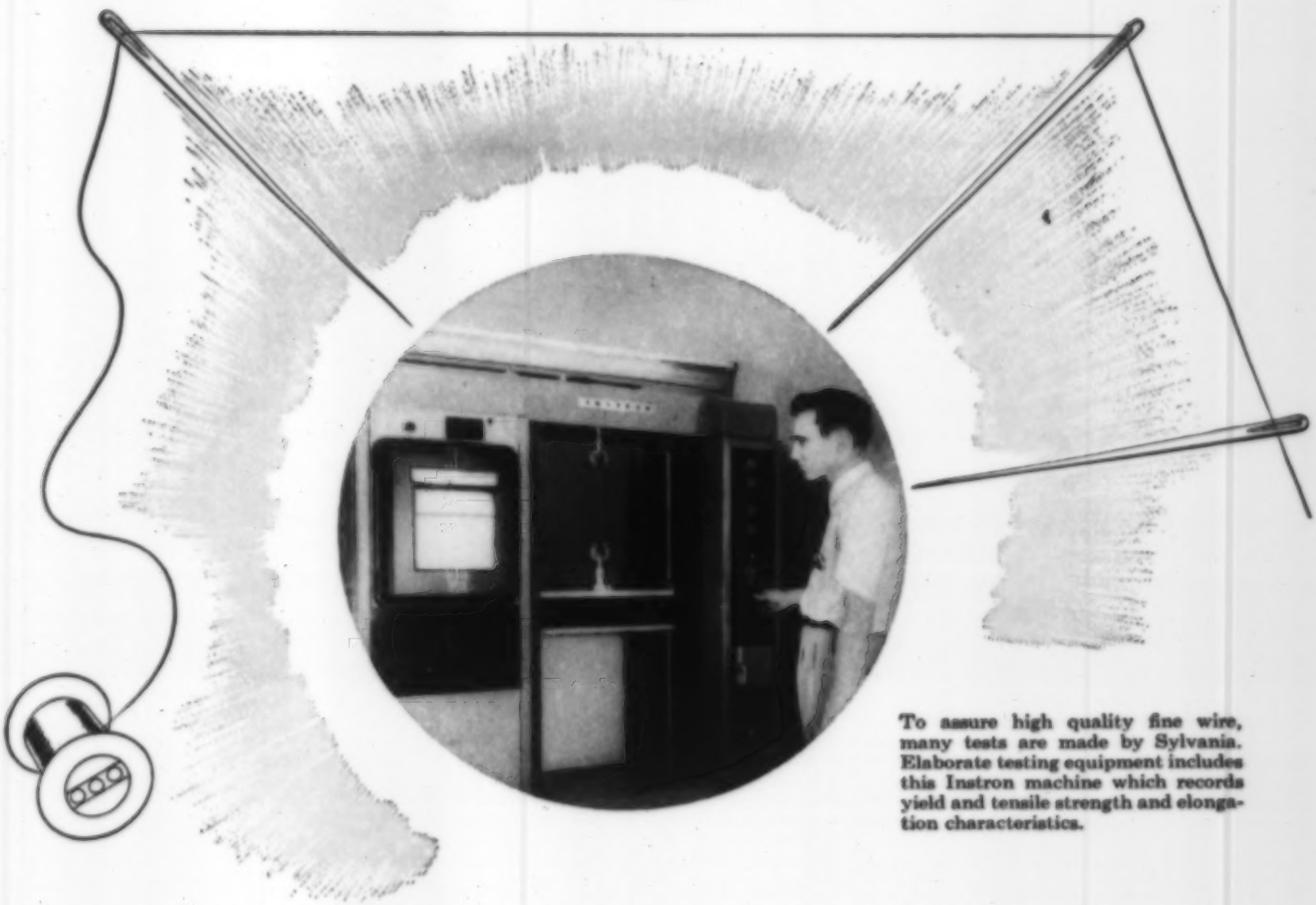
Circle No. 122, Page 247, for more data

Fast-Operating Relay 123

has wiping action

Operating at a speed of 10 milliseconds, model 100-MS relay incorporates a thorough wiping effect. It is available either hermetically sealed or with a dust cover. Designed for dc applications,

A SYLVANIA SPECIALTY "EXTRA FINE" WIRE



To assure high quality fine wire, many tests are made by Sylvania. Elaborate testing equipment includes this Instron machine which records yield and tensile strength and elongation characteristics.

Get "extra fine" diameter wire with the special properties you want

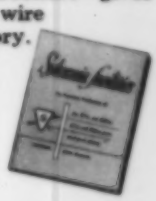
Sylvania is your source for special wire, cold drawn from .250 inch to extra fine diameters of .001, drawn on high speed machines through diamond dies. To insure uniformity, fine wire is strand annealed under carefully controlled temperatures in a protective atmosphere.

Drawing wire in any size from .250 to .001 inch diameters is just one of the reasons Sylvania is a major producer of quality wires. If a wire with special properties can improve product design or cut production costs, Sylvania can produce a composite "made to order." Your composite can be clad or plated in just about any material. You can count on Sylvania to develop the composition wire that best fits your application. Standard plating range varies from "Flash" to 20% by weight. Typical composite wires being produced currently on a custom basis include: nickel on brass; copper on steel; silver on copper; and nickel on steel. There are many others.

Sylvania can also furnish wire flattened to size ⅛" wide or less, and with a knurled surface if desired. Many cross-sectional designs can be rolled, such as half-round and channel shape.

Consult Sylvania on your next special-wire problem—whatever the nature of your product.

New—Wire Facilities Brochure—gives full details on Sylvania's wire and ribbon production story. Write Dept. K533.



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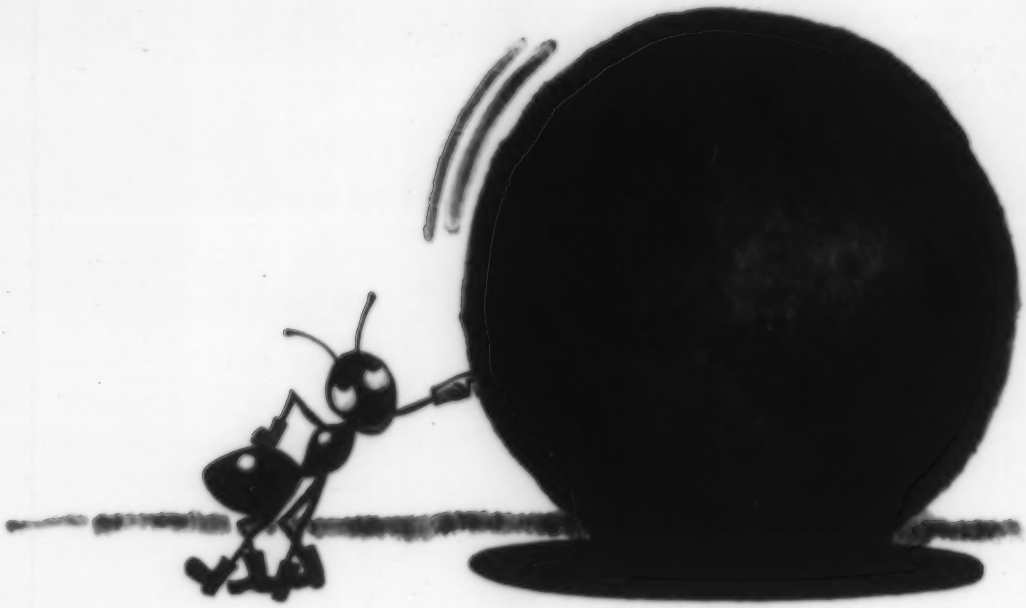

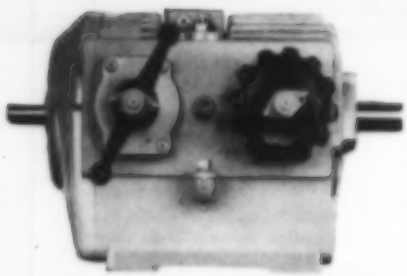

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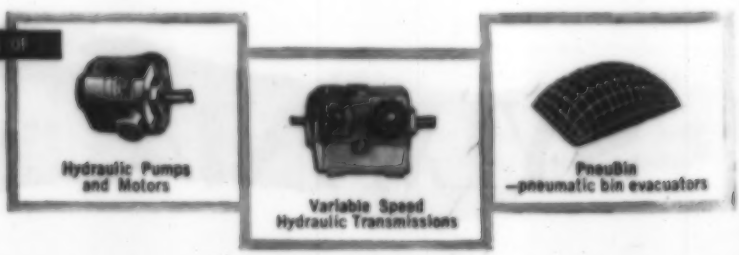


it can have single or double-pole, single or double-throw contacts. Contacts are silver. Capacity is up to 1.5 amp inductive and 5 amp resistive with coil resistance to a maximum of 30,000 ohms. Drop-out, if required, is adjustable to

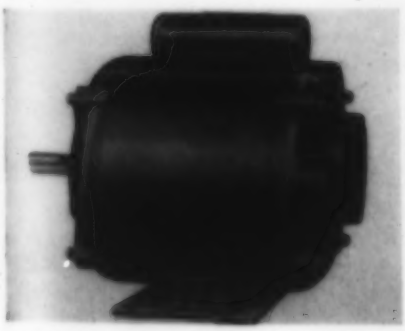
about 65 per cent of pick-up. Wattage requirement is 250 milliwatts per pole. Standard relay is equipped with octal plug-in headers; other types of headers are available. Made by **Hedin Tele-Technical Corp.**, 87 Dorsa Ave., Livingston, N. J.

Circle No. 123, Page 347, for more data

Electric Motors 124

rated ¼, ½ and ¾-hp

Dual-voltage windings and ball bearings are features of these single-phase fractional-horsepower electric motors. They are available in ¼, ½ and ¾-hp ratings



at 1200, 1800 and 3600-rpm speeds for 115 or 230-v 60-cycle ac. They have one-piece, aluminum injection molded squirrel-cage rotors which are dynamically balanced for vibration-free operation. Distributed by **ACEC Electric Corp.**, 40 E. 49th St., New York 17, N. Y.

Circle No. 124, Page 347, for more data

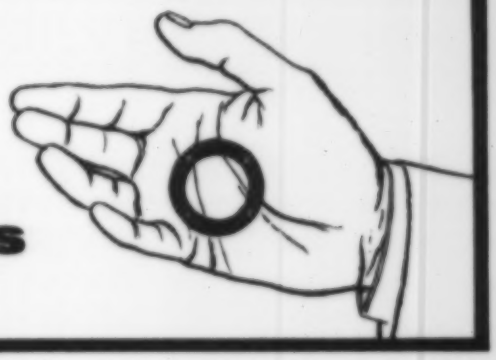
Thermostats 125

can be made to specifications

Built of various standard components to fit individual applications, 20,000 series local-bulb snap-action thermostats provide accurate tem-

(*Continued on Page* 310)

from
Grease Retainers



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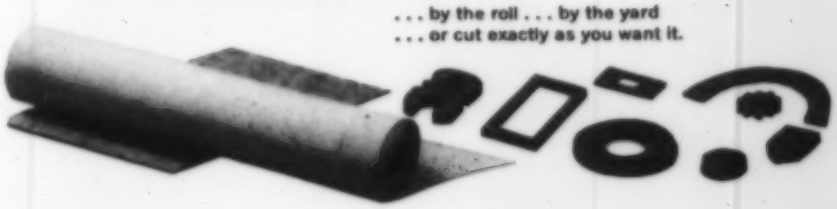
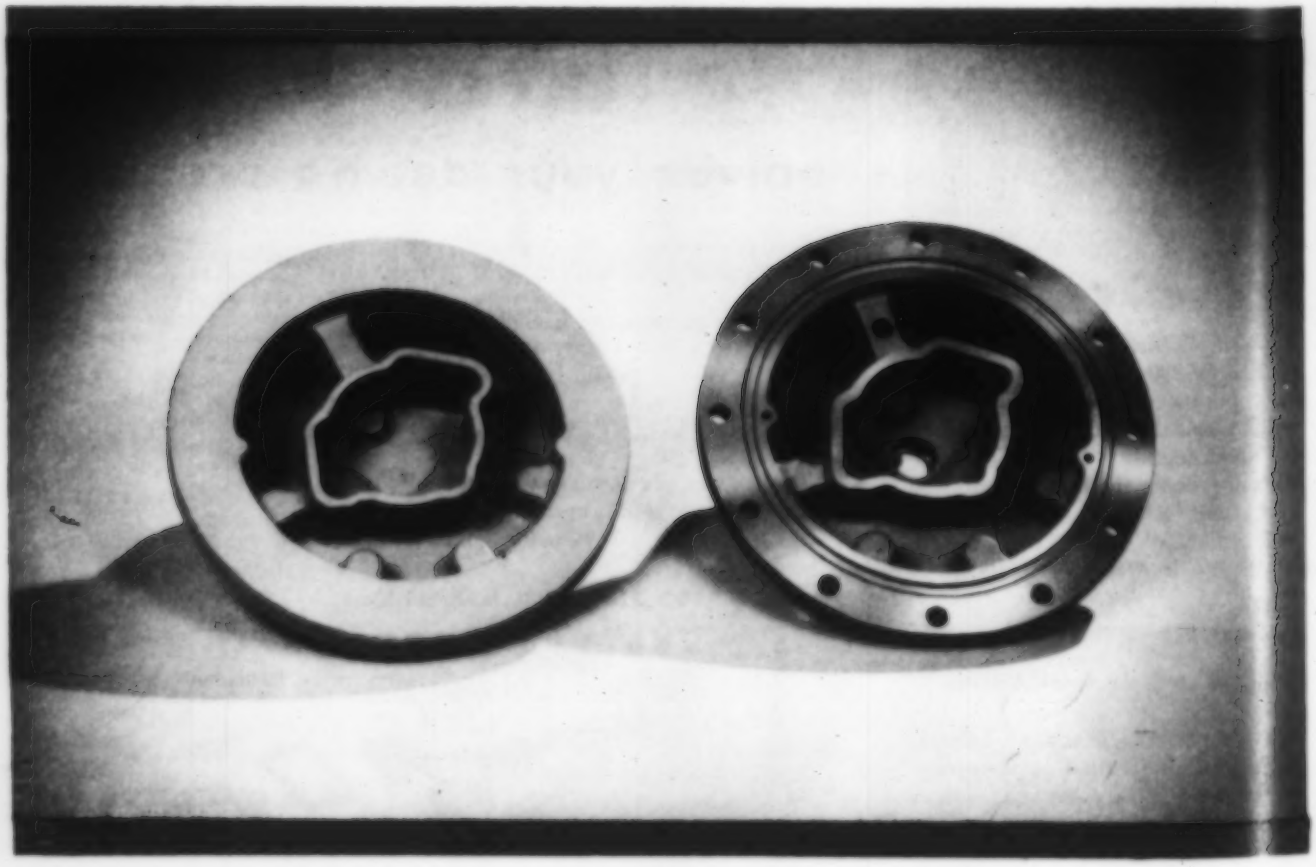


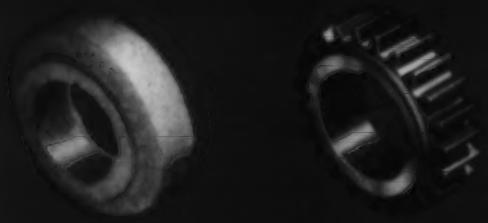
How shell castings + ArmaSteel

This compressor head casting for an air conditioning unit produced by Central Foundry Division is a good example of the improvements and savings so often realized when ArmaSteel and shell castings are combined. This part is subjected to high chamber pressures and must be free of vapor leaks. ArmaSteel has the ideal physical properties for this job including good machinability.

The shell casting process supplies clean, sand-free casting surfaces and greater dimensional uniformity which eliminates costly machining in the chamber, on the O.D. and profile milling on the contour. Thus, by using the shell casting process together with ArmaSteel in this part, material is saved, machining is saved, scrap losses are reduced 80%, and . . . due to ArmaSteel's high physical properties . . . a greatly improved product results.



savings for you



Here are two more parts improved by shell casting. The Crankshaft Sprocket was formerly machined from bar stock on automatic screw machines. By the use of shell castings on automatic chucking machines, material and machining were saved and a product with greater performance resulted.

Rocker Arms are a typical example where the uniformity of shell castings has made the part more adaptable to automatic machining. Preliminary grinding on pad ends has been eliminated, leaving only a finish grind. Center hole is cast with a minimum of finish stock eliminating a preliminary drilling operation.

In **SHELL CASTING** the mold is formed by a thin shell of sand bonded by a thermo-setting plastic. This shell has a hard, smooth surface as accurate as the pattern itself. Shell casting has many advantages:

- **Greater uniformity**
- **Closer tolerances . . . reduced finish allowances**
- **Greater accuracy which makes intricate designs possible**
- **Improved casting surfaces**
- **Freedom from residual sand**
- **Less excess metal resulting in lower freight charges**
- **Longer tool life**

ARMASTEEL is an arrested malleable iron of pearlitic structure. The size and arrangement of carbon nodules in this pearlite result in a freely machining material that has the strength and performance characteristics usually associated with carbon steel forgings. Thus ArmaSteel offers you:

- **Uniform structure**
- **Good machinability**
- **Excellent bearing properties**
- **Good wear resistance under heavy loads at high speeds**
- **Long fatigue life, high yield strength, maximum rigidity**
- **Good damping capacity**
- **Adaptability to selective hardening**

For further information about shell or sand castings, ArmaSteel, malleable iron or grey iron castings, write for descriptive literature . . . or request personal help from our experienced engineers, without obligation.

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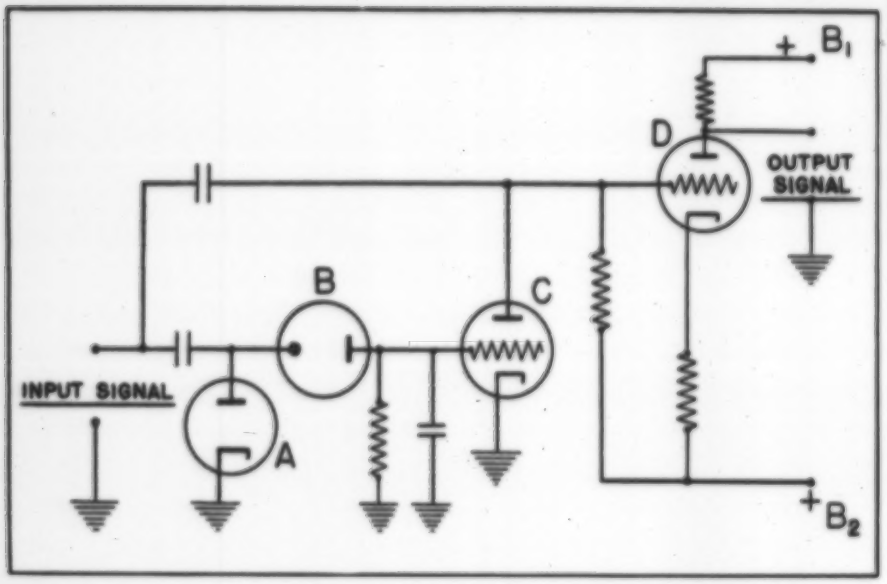

ELECTRONIC AMPLIFYING SWITCHING CIRCUIT

Both electronic switches and electronic amplifiers are used successfully in computer design. A very unusual circuit, patented by the Ford Instrument Company, combines positive switching action with amplification, and is particularly useful in such applications as multi-speed servomechanisms, in which several signals are to be applied selectively to operate the mechanism. When such a circuit is used, the inactive signals can be left connected without producing any noise whatever in the response to the active signal.

The key to the operation of this circuit is the voltage-doubler circuit consisting of diode A and gas tube B. When the signal voltage is below a specified level, gas tube B cannot fire and triode C draws a very large current, making the grid of tube D at almost ground potential. The cathode voltage of triode D is at a voltage B_2 above ground, thereby effectively cutting tube D off. If the signal voltage is above the specified level, gas tube B breaks down, cutting tube C off, thereby permitting tube D to conduct and actuate the servomechanism. The amplification produced by tube D, in addition to providing the required signal level at the servomechanism, contributes also to the effectiveness of the electronic switching, and the resultant circuit is more compact and has a higher parts economy than produced by the use of a separate switch and amplifier.

Electronic circuitry is but one of the many facets of Ford Instrument design and development. Ford Instrument engineers work every day with control systems, using mechanics, electronics, hydraulics, electro-mechanics, magnetics, and atomics. If you have a problem in automatic control, Ford Instrument stands ready to help you.

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ENGINEERS
of unusual abilities can find a future at FORD INSTRUMENT COMPANY. Write for information.

New Parts

(*Continued from Page 307*)

perature control and overheat detection with electrical loads up to 20 amp. The thermostats can be used in gases, liquids or solids in various types of equipment. Four types of enclosures are offered, as illustrated. Temperature ranges of 50 to 300 F, 0 to 250 F and −50 to 200 F are available. Six types of snap switches and either threaded-fitting or flange mounting are offered. Field-adjustable temperature set point and friction locking devices are incorporated in all thermostats, as is a torsion spring arrangement which permits the entire switch to rise under excessive thrusts from the actuating rod. Made by **Fenwal Inc.**, Pleasant St., Ashland, Mass.

Circle No. 135, Page 247, for more data

Diesel Engine 126

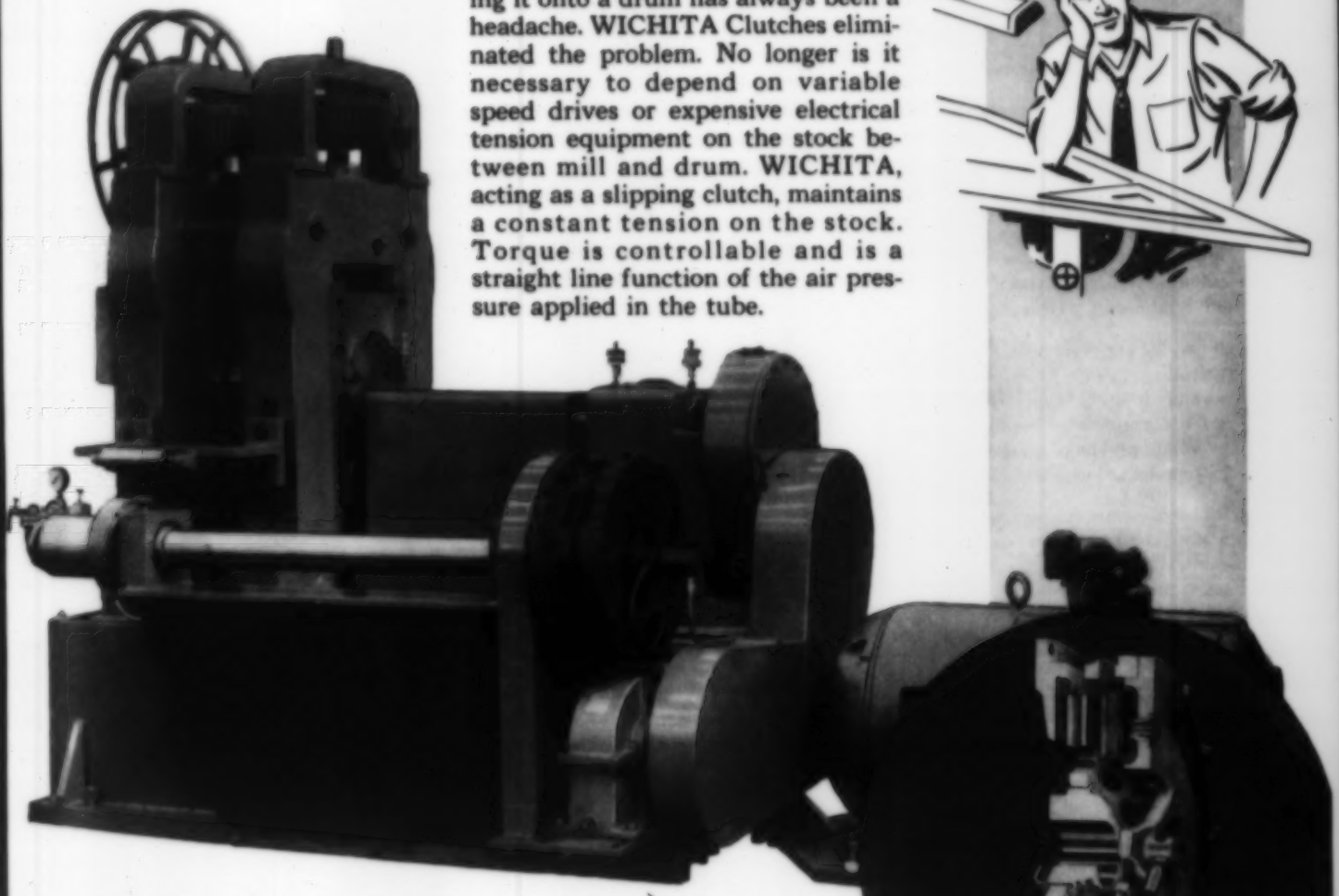
rated 15 hp at 2300 rpm

Power for heavy-duty equipment is supplied by model DRP 15-hp, 2300-rpm, four-cycle diesel engine. The unit is designed for long-running service, is air-cooled and has a compression ratio of 17.3:1. Bore is 3½ in., stroke is 3½ in., and piston displacement is 67.3 cu in. Crankshaft and connecting rods are forged steel with large bearing surfaces. Pistons are Vanasil aluminum alloy, and exhaust valves and seats are of Stellite. A 12-v battery charging gen-

Fenn Manufacturing Company of Newington, Conn., Writes:

"WICHITA WAS THE REMEDY FOR OUR HEADACHE !"

Rolling thin-gage material and coiling it onto a drum has always been a headache. WICHITA Clutches eliminated the problem. No longer is it necessary to depend on variable speed drives or expensive electrical tension equipment on the stock between mill and drum. WICHITA, acting as a slipping clutch, maintains a constant tension on the stock. Torque is controllable and is a straight line function of the air pressure applied in the tube.



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- Extremely Long Life
- Easier Maintenance

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THAN ANY OTHER WORK OF ITS KIND

HANDBOOK OF ENGINEERING MATERIALS

Edited by DOUGLAS F. MINER, Carnegie Institute of Technology, and JOHN B. SEASTONE, Olin Mathieson Chemical Corporation. With 51 contributors

UNLIKE the conventional handbook, the coverage of this comprehensive volume is not limited to any single field. It provides a single source of authentic reliable information on the materials of manufacturing and construction in *all* branches of engineering.

It is of particular value to the specialist working in an area where several fields overlap—and ideal for the engineer or student facing materials problems involving areas of knowledge outside his own field.

Its arrangement makes easy the ready comparison of competitive substances and also serves as an index of alternative materials where the preferred material may not be available. Compact and easy to use, it covers all main factors involved in the selection of a material and provides references for information on an almost inexhaustible range of substances.

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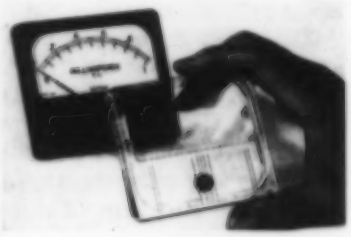
New Parts

erator and 12-v electric starter are standard. Engine has full-pressure lubrication. Made by **D. W. Onan & Sons Inc.**, University Ave., S.E., at 25th Ave., Minneapolis 14, Minn.

Circle No. 126, Page 247, for more data

Panel Instruments 127

available with colored plastic front sections



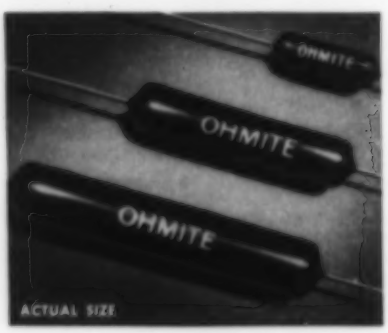
Model 1331 line of flush-mounted electrical indicating instruments incorporates a self-shielded movement which eliminates all inter-effect when meters are mounted closely on the same panel. Mounting on magnetic or nonmagnetic panels is possible without special adjustment. Available as dc or rectifier type ac instruments in standard ranges, these panel meters have one-piece, snap-on fronts with zero correctors. The entire front surface, except for the window area, can be supplied in any color or black. Made by **Weston Electrical Instrument Corp.**, 614 Frelinghuysen Ave., Newark 5, N. J.

Circle No. 127, Page 247, for more data

Power Resistors 128

have axial leads

Available in an extensive range of sizes and ratings, these small power type resistors have axial leads. They are wire-wound units, with steatite cores and vitreous enamel coating. Resistance wire and terminal lead are both welded to the



POSITIVE race to shaft holding power and EASE of mounting are yours with SEALMASTER *ZONE HARDENED* BALL BEARING UNITS

ZONE HARDENING
what it is and what it does

Zone Hardening is a completely automatic process of heat treating with timing scientifically controlled to tenths of a second. In addition to the features outlined in this ad, it provides for a finer grained metallurgical structure of uniform hardness in the ball path section. This assures better load carrying capacity and longer life.

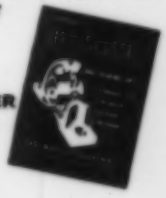
Slip a SEALMASTER Ball Bearing Unit into place on the shaft—tighten two set screws and you have the answer to ease of mounting and positive holding power in a ball bearing unit. SEALMASTER's exclusive Zone-Hardening process makes it all possible!

With Zone-Hardening, only the ball path section is through hardened—leaving the extended portion of the inner-race in its metallurgically soft, tough state. This soft portion provides a firm bind for hardened set screws which positively lock the race to the shaft.

In addition to the above, SEALMASTER Ball Bearing Units provide the following exclusive combination of features:

- ✓ **Patented LOCKING PIN & PERIMETER DIMPLE prevents rotation of outer race and assures positive lubrication.**
- ✓ **Patented BALL RETAINER—Land ridden ball retainer eliminates ball wear, traps grease and prevents churning.**
- ✓ **Patented SEAL keeps dust and dirt out and lubricant sealed in for long bearing life.**

Full information on SEALMASTER bearing units are contained in this FREE bulletin.



SEALMASTER BEARINGS A Division of STEPHENS-ADAMSON MFG. CO., 18 Ridgeway Ave., Aurora, Ill.

Low oil seal for every purpose!

Universal Oil-Seals are assembled units ready for installation at vital friction points. They are available in special designs up to 48" diameter shafts with optional leather, synthetic rubber or composition packings.

STANDARD SEALS CARRIED IN STOCK. WRITE FOR COMPLETE CATALOG.

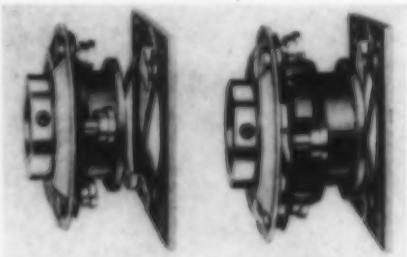
UNIVERSAL OIL SEAL CO.
PONTIAC 12, MICHIGAN

end cap to assure permanently stable electrical connections. Smallest resistor measures ¼-in. diameter by 19/32-in. long and is rated at 3 w. Two sizes, rated at 5 and 10 w, are available in a wide range of resistance values. Made by **Ohmite Mfg. Co.**, 3678 Howard St., Skokie, Ill.

Circle No. 128, Page 247, for more data

Safety Switch 129

prevents overloads and underspeeds



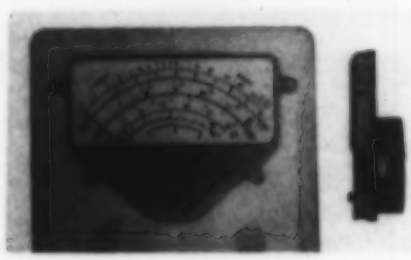
Protection against overloads, belt slippage and breakage, and other conditions which would reduce speed on mechanical or electrical devices, is provided by this Syncro-Snap underspeed centrifugal switch. At a predetermined minimum rotational speed, the switch will operate to stop the unit on which it is used. Positive snap action eliminates the tendency to flutter and provides fast, arc-free opening of the stationary switch contact points. Action is determined by speed only, regardless of voltage or load. Made by **Torq Engineered Products Inc.**, 34 Interstate St., Bedford, O.

Circle No. 129, Page 247, for more data

Panel Meter 130

has large dial face

The 6 x 2½-in. dial face of the SS56 meter makes possible rapid, accurate readings from a distance. Or, several scales can be combined in one instrument. The meter is designed for mounting behind the equipment panel. It is available as a moving-coil permanent-magnet type in all dc ranges. Standard models are accurate within 2 per cent, although accuracy to 0.5-per cent can be specified. A variety of scale ranges is offered. The meter's clear acrylic plastic cover allows for exterior or edge lighting; internal scale lighting is also possible. Made by **Marion Electrical Instrument Co.**, Manchester, N. H.



Circle No. 130, Page 247, for more data

Synthetic Rubber 131

resists heat and corrosion

Thermosetting Hypalon is an elastomer made of chlorosulfonated polyethylene. Products made from this material are similar in appearance and physical characteristics to those made from other rubbers. Highly resistant to heat, Hypalon retains useful elastomeric properties at continuous operating temperatures up to 300 F. Neither ozone nor weather conditions affect the material appreciably, and parts made of it operate in sulfuric and chromic acid solutions, hydrogen peroxide, calcium hypochlorite and other strong oxidizing agents. Made by **E. I. du Pont de Nemours & Co. Inc.**, Elastomers Div., Wilmington 98, Del.

Circle No. 131, Page 247, for more data

Pulse Generator 132

employs saturable reactors

Model MP 414-A magnetic trigger generator operates hydrogen thyratrons. Using saturable reactors in its design, this capacitor type pulser stores electrical energy in an ac resonant charging circuit. Rapid discharge of the condenser through the reactors releases the electric pulses. Because the generator is a line type pulser using ac power, its pulse repetition rate is that of the line frequency. Circuit components are hermetically sealed in a can 1⅞ x 1 13/16 x 3 in. The unit weighs 14 oz. It operates at temperatures from −40 to 85 C. Made by **Magnetic Research Corp.**, 200-202 Center St., El Segundo, Calif.

Circle No. 132, Page 247, for more data

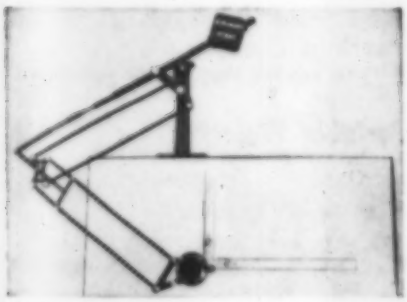
ENGINEERING DEPARTMENT

EQUIPMENT

Drafting Machine 133

precision instrument built on parallelogram principle

Design of precision German-made Kuhlman drafting machines is based on the parallelogram system for high accuracy. At any point on the board, deviation from parallelism does not exceed 0.6-minutes of arc, or 0.00017-in. per in. The 15-deg index intervals are accurate



within 0.6-minute also. Design of the anchor casting brings the point of suspension far enough away from the top edge of the board so that unrestricted drawing is possible at the anchor. Pivots are incoroporated in the anchor to permit lifting the machine off the board any distance for insertion and placement of paper on the board. Base-line adjustment is accomplished by means of an eccentric mechanism. Models are available for use on vertical or horizontal drawing boards 32 x 47, 39 x 59 and 49 x 79 in. in size. Available from **Evenline Products,** P. O. Box 47, East Side Station, Providence 6, R. I.

Circle No. 133, Page 247, for more data

Drafting Board Lamp 134

provides 100 ft-c of light

The Draft-o-Lamp illuminates the entire surface of a drafting board with 100 ft-c of shadowless light. The lamp is 4 ft long and uses two 40-w fluorescent lamps. It clamps on the back of any size

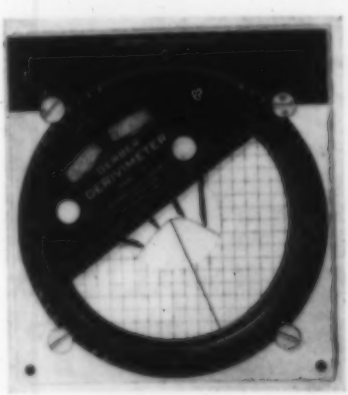
drafting board. Height is adjustable. Made by **Midwest Lighting Products Co.,** P. O. Box 536, Cleveland 7, O.

Circle No. 134, Page 247, for more data

Slope Reader 135

does not require computation

The Derivimeter, designed to obtain the derivative or slope of a plotted curve, yields the normal as well as the slope directly, without computation. The exact equation of the graphical curve need not be known to determine derivatives; however, if an equation is available, a simple plotting of the area of interest on co-ordinate axes allows the instrument to determine the slopes. This instrument also can be used in such problems as the layout of cams, in layouts involving tangents and intersections to the curve lines in aircraft design, and the compiling of velocity and acceleration data from displacement curves. Having few moving parts, the instrument re-



There are BIG advantages of shifting over to the ELECTRONICS INDUSTRY!

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Bendix Radio

DIVISION OF BENDIX AVIATION CORP.
TOWSON 4, MARYLAND

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1433 EAST STATE STREET TRENTON, N. J.

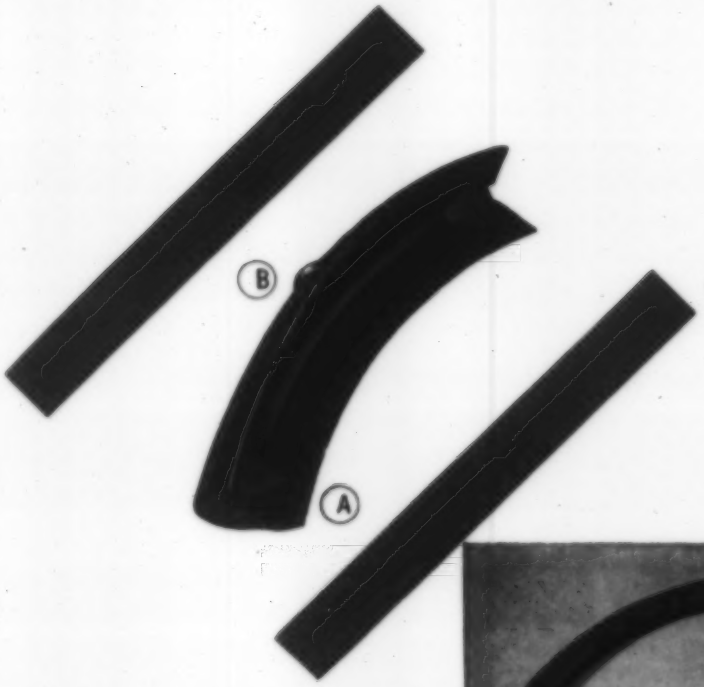
mains in calibration and retains its accuracy over a long period of time. Components include a flexible flat spring mounted on a pivot at its center and an indicator mounted perpendicular to the spring at the center. This indicator registers on a circular scale, and any deflection of the spring or rotation about the pivot pin is transmitted to the scale. The scale is divided into four quadrants to indicate the sign as well as the numerical value of the derivative. Operation of the instrument involves placing the pivot at the point of interest on a given curve, adjusting the spring to coincide with the shape of the curve and reading the derivative from the scale. Made by **Gerber Scientific Instrument Co.**, 162 State St., Hartford, Conn.

Circle No. 135, Page 247, for more data

Portable Projector 136

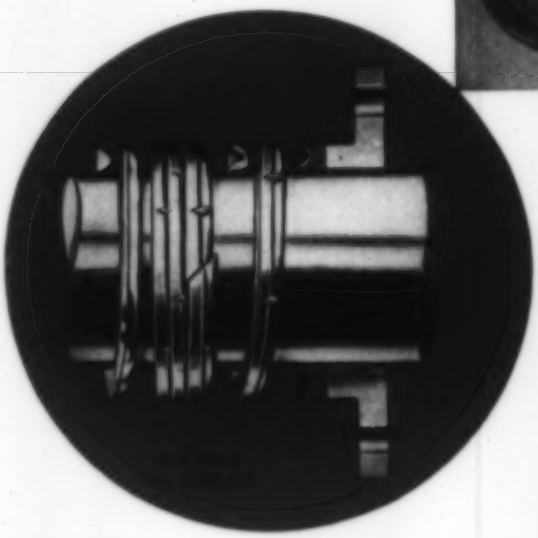
enlarges or reduces up to 400 per cent

Camera Lucikon, model B, projects an image which is up to four times larger or smaller than the opaque drawing or three-dimensional object placed on the 17 x 22-in. copy board. The projected image appears on tracing paper or other transparent material on the 11 x 14-in. drawing surface. Working area is 29 in. from the floor. A hood is provided to permit operation in a well illuminated room. Both the lens board and the copy board have parallel adjustment on all four corners to assure accurate projection. The 25-lb unit is mounted on casters to permit movement



Really leakproof!

Linear VEE-DAM® rings



HERE'S A UNIQUE, revolutionary split V-Ring design that positively stops both labyrinth flow and lateral leakage!

LINEAR VEE-DAM RINGS don't require precise fitting. Even when gaps occur at the ring joints, through careless installation or variations in bore size, fluid can't leak past the rings. Here's why: *Sturdy Rubber Dams* (A) in the grooved hinge area hermetically seal off center groove sections. When rings are stacked together, these dams eliminate all labyrinth flow. *External abutments* (B) on the ring shoulders prevent lateral leakage and provide stabilizing support.

Let us show you how LINEAR VEE-DAM RINGS, engineered to your application in a choice of fabric reinforced synthetic rubbers, save you installation and maintenance time, and assure you absolutely leakproof packing over a wide temperature range.

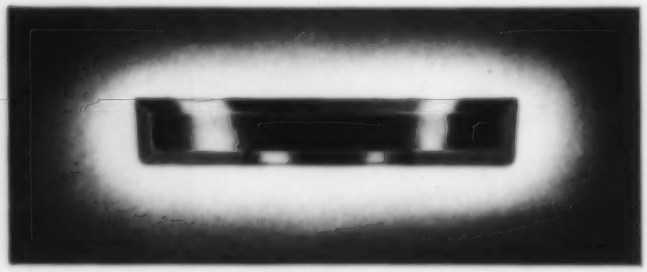
PERFECTLY ENGINEERED PACKINGS

LINEAR

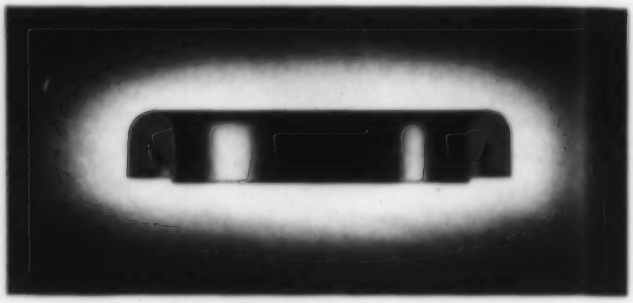
LINEAR, Inc. STATE ROAD & LEVICK ST., PHILA. 35, PA.

Simplify your sealing problems...

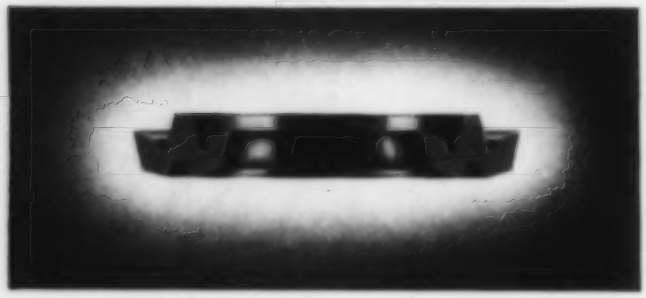
with Johns-Manville Precision moulded packing designs for pressure applications in hydraulic and pneumatic equipment



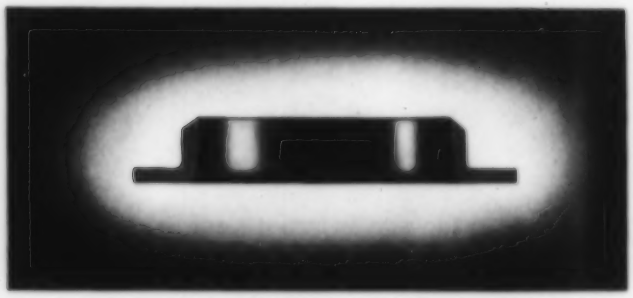
1. Type "A" Packing Cups for pistons
(the original "square heel" cup design)



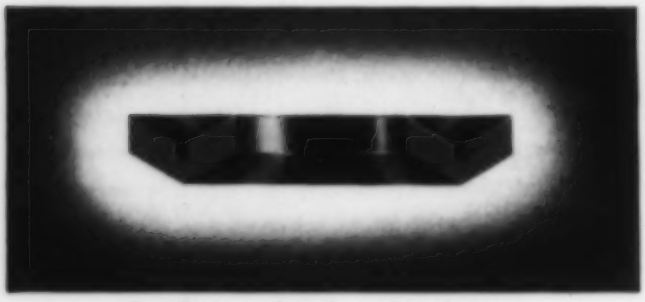
2. Sea Ring packing for rods



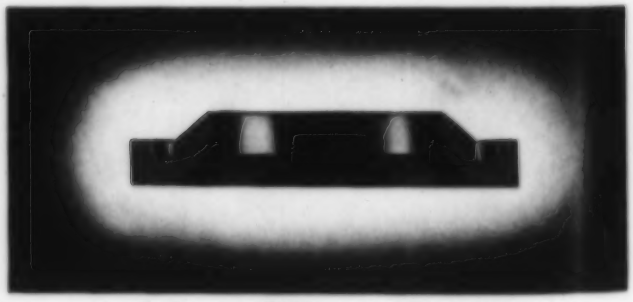
3. Uneepac Packing for rods and pistons



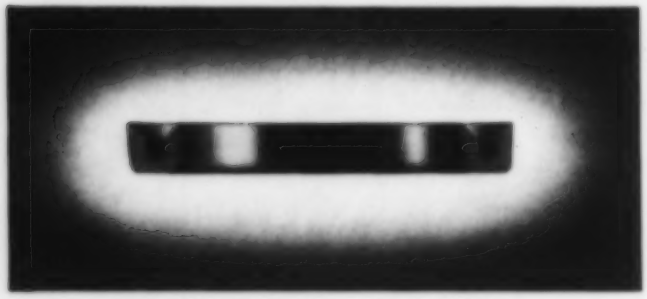
4. Hat Cup Packing for rods



5. V-Rings packing for rods and pistons



6. Cumpac #239 packing for rods



7. U-Cup Packing for rods and pistons

THE WIDE VARIETY of Johns-Manville Packing designs enables you to handle practically any sealing problem. The designs shown on this page are obtainable in a broad range of standard sizes and in materials designed for either usual or special service conditions encountered in hydraulic and pneumatic equipment. Johns-Manville also produces oil seals, moulded gaskets and miscellaneous shapes to specification. See your local J-M distributor or J-M sales office for product or engineering data. Or write Johns-Manville, Box 60, New York 16, N.Y. In Canada, Port Credit, Ontario.

JM PRODUCTS

Johns-Manville MOULDED PACKINGS

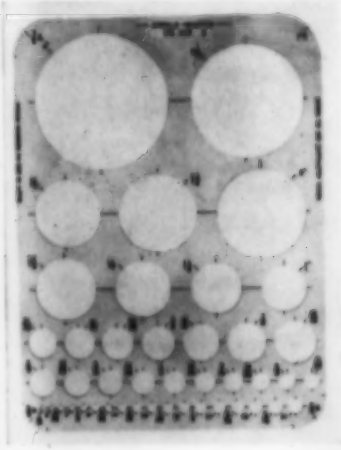
from one working area to another. Overall floor area required is 18 x 22 in. Made by **M. P. Goodkin Co.**, 889 Broad St., Newark 2, N. J.

Circle No. 136, Page 247, for more data

Circle Template 137

has circles from 1/16 to 3 in. diameter

Forty-four precision milled circles are found on the Circle-Master template, made of rigid, nonglare acrylic vinyl plastic. Circles are grouped in progressive sizes. Diameters from 1/16 to 11/32-in. are in increments of 1/64-in.; from 3/8 to 3/4-in. in increments of 1/32-in.;



from 13/16 to 1 in. in 1/16-in. increments; and from 1 1/8 to 1 1/2 in. in 1/8-in. increments. Also included are 1 3/4, 2, 2 1/2 and 3-in. circles. All make allowance for a pencil clearance of 1/32-in. Four corners of the template are cut to give radii of 5/8, 3/4, 7/8 and 1-in. Made by **Alvin & Co.**, Palisado Ave., Windsor, Conn.

Circle No. 137, Page 247, for more data

Spring Computer 138

provides direct answers to spring design problems

The Calculaide spring computer correlates, in one setting, all the variables in spring design, namely outside diameter of the spring, wire size in diameter and gage number, number of active coils, material and its torsional modulus, maximum shear stress, load and total deflection. All figures are read off directly without intermedi-

(*Continued on Page* 324)

Ruthman GUSHER coolant pumps

Designed FOR BETTER PERFORMANCE

Ruthman Gusher Coolant Pumps offer you simple yet sturdy design features. There are no friction seals or packing. The Gusher is always primed, gravity insures immediate pump action. Pre-lubricated heavy-duty ball-bearings require no further attention and the dynamically balanced rotating shaft eliminates vibration. Specify Gusher Pumps for better performance.

Illustrated is a HANCHETT Model AK Traveling Wheel Head Knife Grinder equipped with a Gusher Pump

THE RUTHMAN MACHINERY CO.

1811 Reading Road Cincinnati, Ohio

here's the
for Chain Drive users
FREE
answer to better low-cost power transmission...
Write today for the first really Engineered approach to the problem of supplying custom sprockets "off-the-shelf"
your shaft size + bushing + sprocket = Grip-Master stock delivery
Low installation cost Low maintenance cost All sizes in steel No extra machining needed!
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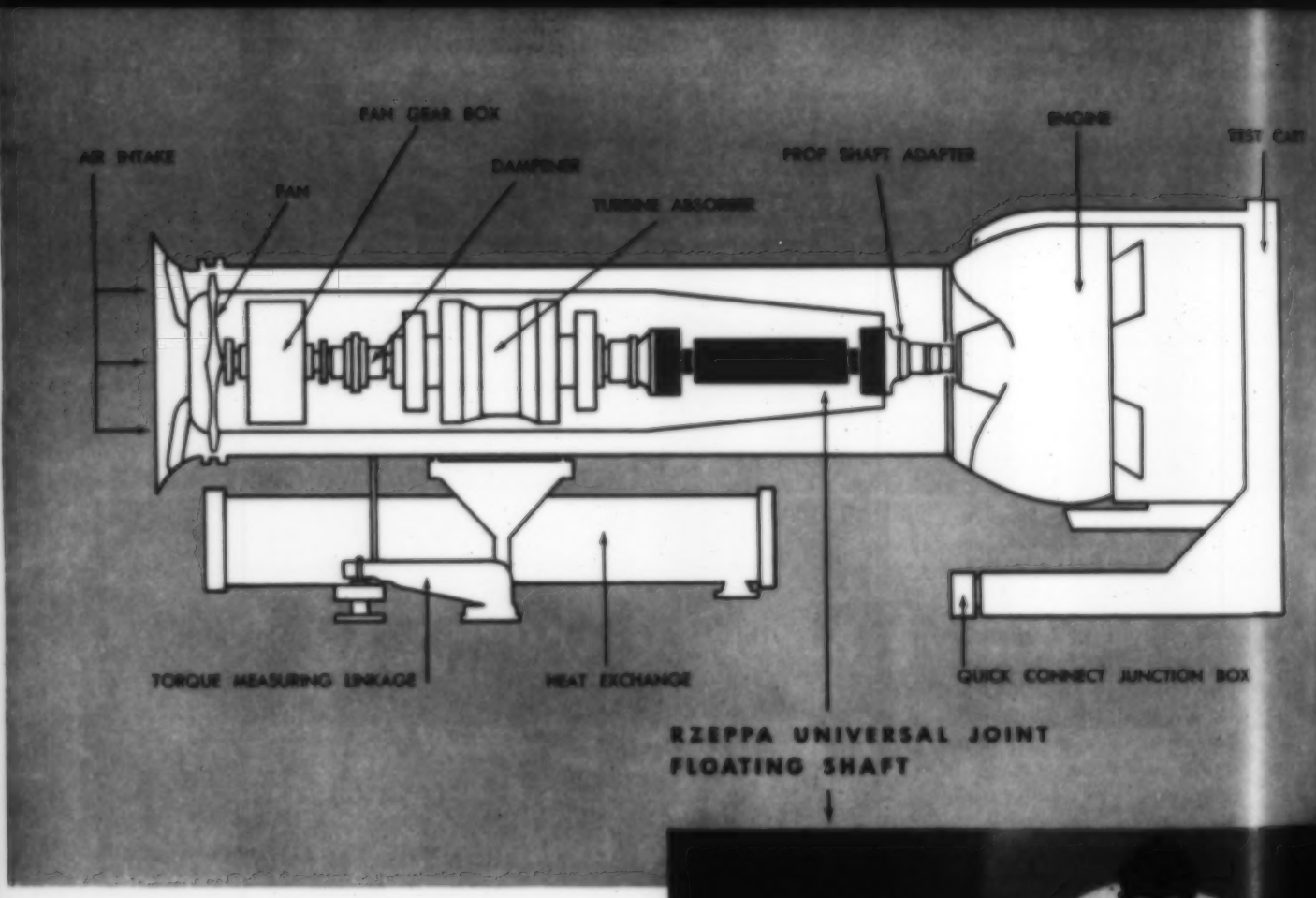
Why RZEPPA Universal Joints were selected for first packaged aircraft test facility



ABOVE: The world's first completely packaged aircraft engine test facility, shown in the diagram above, is installed at the Trans-World Airlines Overhaul Base, Kansas City, Kansas. Recently introduced by the Clayton Manufacturing Company of El Monte, California, the unit-built machine includes a turbine power-absorber, engine cooling fan assembly, and floating shaft connecting two Rzeppa Constant Velocity Universal Joints.

The dynamometer, which gives rebuilt engines their final check, eliminates the laborious connecting and disconnecting of test cell procedure. The result: more engines tested per facility.

RIGHT: The huge cone-type universal joint assembly (16¼ inches O.D.) believed to be the largest ever manufactured, is an integral part of the three-unit facility. Specifications for size, precision, constant rotating motion were exacting —and Clayton turned to Rzeppa.

An application where performance really counts

Here's what The Clayton Manufacturing Co. required of a universal joint assembly

1. The assembly, from engine to dynamometer, should not exceed six feet.
2. It must be capable of concentric and parallel alignment of propeller and dynamometer shafts.
3. Universal joint assembly should accommodate angular deflections of ±3°44′ on the propeller shaft end and ±1°40′ on the dynamometer end.
4. Preferred minimum rating of assembly:
   (a) 3500 hp at 1150 rpm
   (b) a maximum speed of 1260 rpm (at 2800 hp)
5. Life expectancy of the joint assembly should be 10,000 hours.
6. Maximum O.D. of universal joints should not exceed 22 inches.
7. Minimum end float of the universal joint assembly shaft should be ±0.175 inches.

Here's how the Rzeppa joint assembly EXCEEDED Clayton's specifications

1. Shaft length between engine end and dynamometer end is *less than* four (4) feet.
2. Rzeppa Joint's constant velocity eliminated alignment requirements.
3. The assembly provides a rating of 5000 hp at 1200 rpm.
4. Has a life of 10,000 hours.
5. Maximum O.D. of joints is 16¼ inches.
6. Shaft float at zero angularity is ±.375 inches minimum and ±0.5 inches maximum.

In addition, Rzeppa offered these advantages:

1. Great torsional stiffness.
2. No vibration.
3. Safe critical speed.
4. A constant torque characteristic.
5. Zero radial forces due to angular operation.
6. Very high efficiency shown by low temperature rise during operation.

How Rzeppa True Constant Velocity Works for you

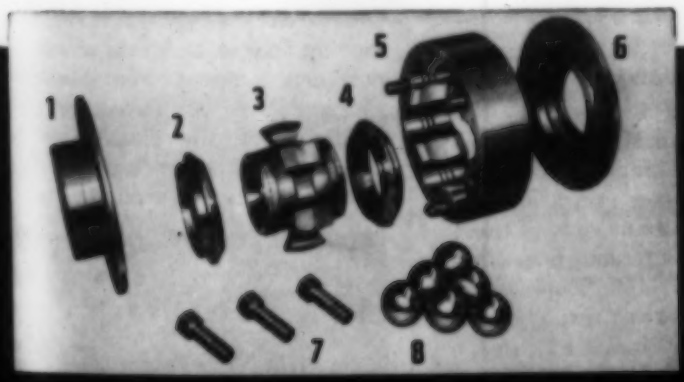
- High Angle Efficiency
- High Capacity
- Ruggedness
- Compactness
- Long Life

The principle of Rzeppa True Constant Velocity has proven itself over a quarter-century in a wide range of industries, for an even wider range of applications. It is this principle which eliminates speed fluctuation and vibration.

Today, low angle-high speed Rzeppa disc type joints are used on power take-off shaft drives on aircraft (up to 3° at 8,000 rpm). High angle-low speed Rzeppa bell type joints permit continuous minors to vary their working angle up to 35° at 400 rpm.

Your joint application lies somewhere between these two. And Rzeppa Constant Velocity Universal Joints offer you more effective performance by transmitting a uniform flow of power. Whether your application calls for disc or bell type, you get a rugged, versatile universal joint—a joint that carries heavier loads for its size than any other type

What joint applications do you have that could use performance advantages like these? Our catalog may help answer that for you. Send for it today.



Patented construction principles of the Rzeppa Universal Joint permitted Geargrind to design and construct a joint assembly exceeding the Clayton Company's joint assembly specifications. Exploded view shows (1) outer cover, (2) and (4) piloting rings, (3) inner race, (5) outer race, (6) shaft end cover, (7) mounting and driving bolts, (8) hardened steel balls.

RZEPPA

pronounced "SHEPPA

Constant Velocity

UNIVERSAL JOINTS

JOINT DIVISION
THE GEAR GRINDING MACHINE CO.
3937 CHRISTOPHER, DETROIT 11, MICHIGAN

Manufacturers of
- Fully Automatic Gear Grinding Machines
- The DETROIT SCREWMATIC 750

Photo courtesy American Sterilizer Co., Erie, Pa.

"Just What the Doctor Ordered"

New Super-Soft Rubber Pads Developed for Surgical Table Headrest

This surgical patient's head is in firm but gentle hands. The tight grip of the surgical table headrest shown above is now cushioned by super-soft (20 durometer) solid rubber pads. These pads are almost as soft as sponge but can be decontaminated and sterilized far more easily. Being made of neoprene, they are unaffected by oils, acids or decontaminating and sterilizing solutions. Furthermore, repeated sterilizing in live steam does not cause excessive hardening.

The neoprene compound specially developed for this purpose is 10 to 15 durometer points softer than normal commercial limits. For that reason, special care and skill must be taken in mixing and molding.

The successful development of this special purpose rubber part typifies the complete engineering and laboratory—as well as manufacturing—service offered by Continental.

Why not let Continental engineers consult with you in the planning or blueprint stage? Their specialized skill might help you get better rubber parts for your requirements.

Engineering catalog.

In addition to custom-made parts, Continental offers an extensive line of standard grommets, bushings, bumpers, rings and extruded shapes. Hundreds of these standard parts are shown in Continental's No. 100 Engineering Catalog. Send for a copy today. This catalog also is shown in Sweet's File for Product Designers.

Another achievement in **RUBBER**

engineered by **CONTINENTAL**

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Engineering Equipment

(*Continued from Page 321*)

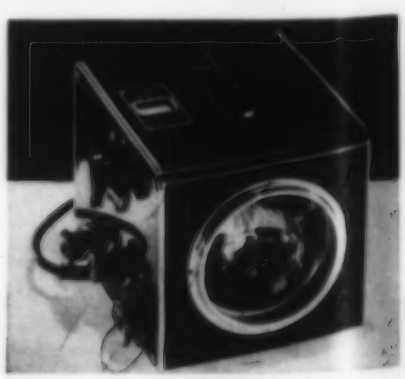
ate computation; no reference is made to a standard load, or a standard torsional modulus, or a standard number of coils. The stress scale includes the correction for nonlinear distribution of torsional stresses in curved wires. This computer also gives correct results for great deflection of extension springs, in which case the contraction of the coil diameter at steep helix angles causes a stiffening of the spring, reducing the deflection below the values obtained from customary formulae. It is 11 in. long and made of Vinylite plastic, which is dimensionally stable and unaffected by moisture or ink. It can be cleaned with a damp cloth. Made by **American Hydromath Corp.**, 25-20 43rd Ave., Long Island City 1, N. Y.

Circle No. 138, Page 247, for more data

Portable Stroboscope 139

reads directly in 250 to 18,000 rpm range

Rapid measurement of speed and the study of rotating and vibrating or reciprocating mechanisms can be made in slow motion using this portable Strobofiash. Unit's circuit comprises an oscillator with built-in variable speed control having a calibrated dial graduated in flashes per minute. This oscillator is used to drive the neon flash tube mounted within the parabolic reflector. Direct reading range is 250 to 18,000 rpm in three overlapping ranges, accurate within ±1 per cent. Speeds outside scale range can be measured by using multiples of the flashing speed. The practical upper limit of speed measurement is around 100,000



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3. YOUR section is obtainable in a wide range of analyses . . . and, in addition, it will possess the physical benefits and accurate tolerances derived from cold drawing.
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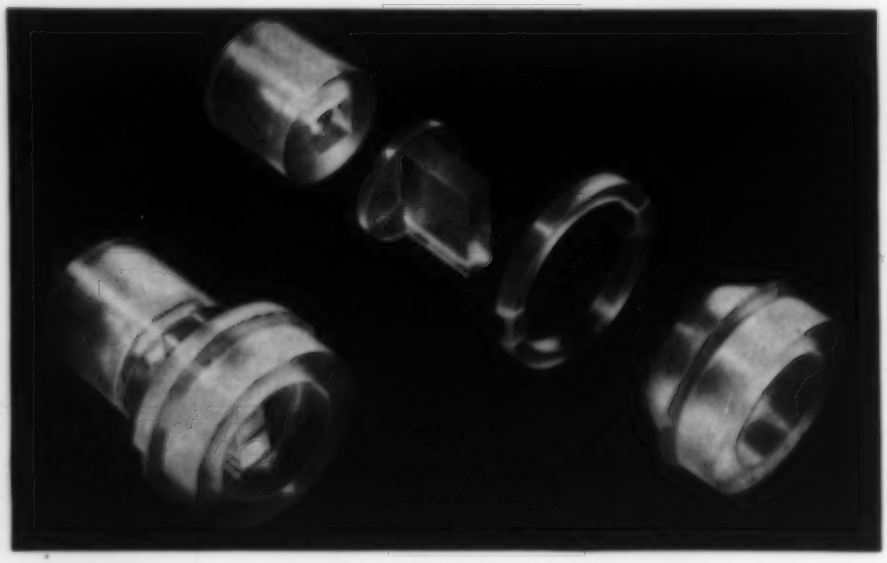


prove it works

before you go into production

Machine that part from polystyrene and let us investment-cast it in the metal you plan to use. Test it and, if some change is indicated, repeat the process until you have the final answer. This cut-and-try method of proving a design and an alloy saves you a lot of time and money.

Polystyrene machines readily and is inexpensive. Complex patterns can be made in sections and assembled, then cast as a unit just as they'd be investment-cast in quantity. Thus parts for testing are exactly like you'll get in production, but they cost far less than cutting them out of metal.

Technical Data Available

When your idea is on paper, but before you start to make the polystyrene patterns, send us a blueprint. We'll figure the shrinkage factor for you, suggest possible gating arrangements and design modifications which may effect further economies.

The pamphlet, *A Guide for Making Polystyrene Patterns*, describes methods of machining and names sources from which this material can be obtained. For a free copy, write Precision Metalsmiths, Inc., 1083 East 200th Street, Cleveland 17, Ohio.

Let's discuss this idea at the Metal Show, Booth 1761, Philadelphia, Oct. 17-21.

pour yourself an assembly with

PRECISION METALSMITHS, Inc.

Investment Castings

rpm. Flash duration is between 10 and 15 microseconds. Flashing speed can be controlled by an external contactor, by power line frequency, or by an external voltage source, if desired. Accessories include a contactor head for synchronism with mechanical spindle, pistol grip lamp and three high intensity stroboscopes with greater light outputs than the standard unit. Made by **Hickok Electrical Instrument Co.**, 10634 Dupont Ave., Cleveland 8, Ohio.

Circle No. 139, Page 247, for more data

Visual Tachometer 140

measures speeds at distances to 50 ft

Rotary or vibratory speeds of machinery or equipment can be measured from distances of 3 to 50 ft with this light-weight Visutac visual tachometer. It has a spring-wind mechanism which stops motion on a stroboscopic principle. It is available in two basic ranges of 500 to 8000 and 1000 to 16,000 rpm or vibrations per minute. It is accurate within 2 per cent. Instrument can be wound, focused, synchronized to stop motion and read at leisure. Available from **Boulin Instrument Corp.**, 65 Madison Ave., New York 16, N. Y.

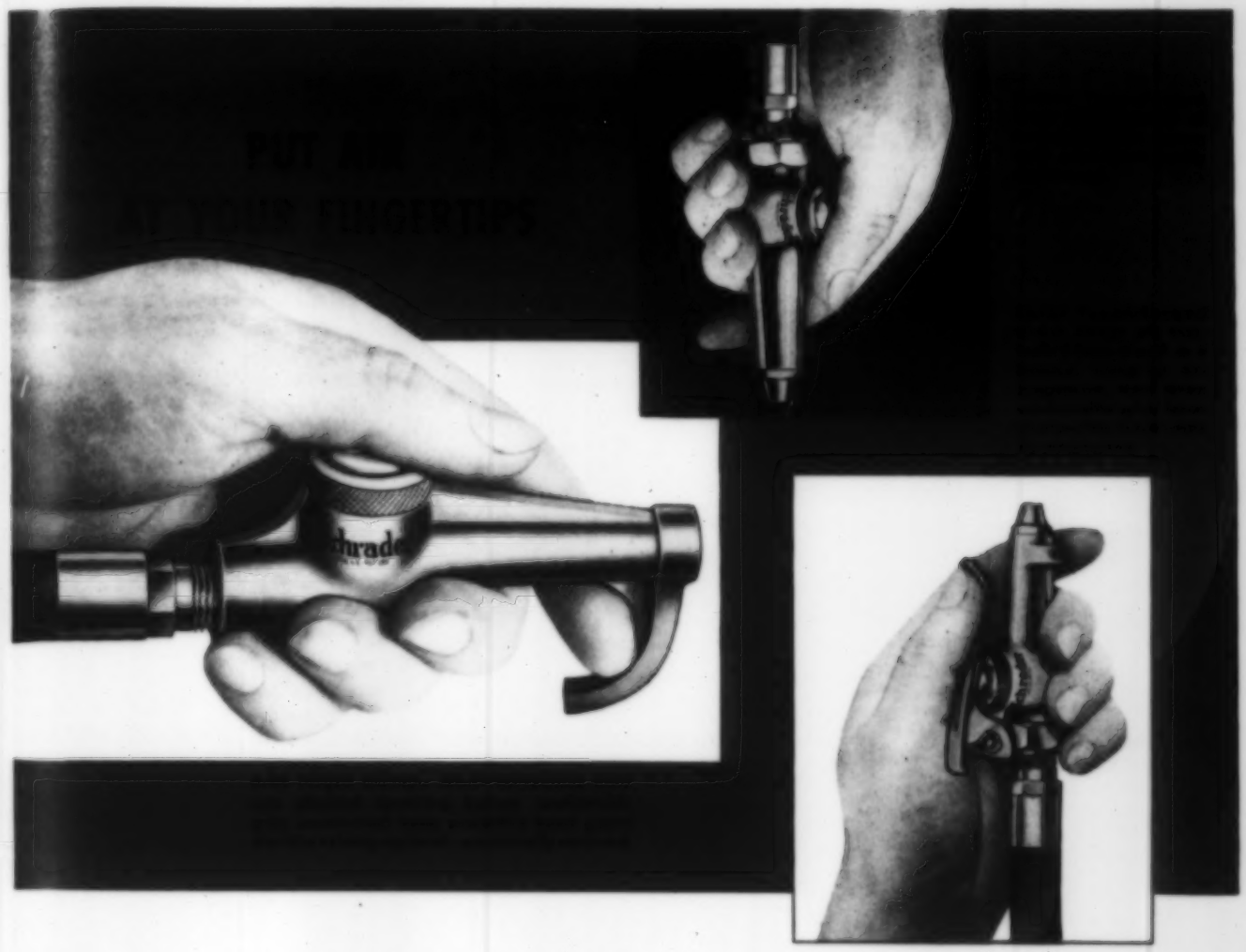
Circle No. 140, Page 247, for more data

Ruling Pen 141

has chromium plated nibs

The Rule-O-Matic ruling pen now has hard chromium plated nibs, which improve performance, resist dampness and abrasion and prevent tarnishing and corrosion. The cartridge-fed pen contains enough India ink to draw 55,000 in. of lines. Made by **Rule-O-Matic Corp.**, 38 E. 57th St., New York 22, N. Y.

Circle No. 141, Page 247, for more data



Use Schrader blow guns . . . 36 designs and styles

Schrader Blow Guns are made to *fit your hand . . . fit your job!* Schrader Blow Guns are built to take it—here's why:

They're rugged both in design and construction. Bodies are drop-forged either of brass or stainless steel.

They're convenient—can be used anywhere. Blow gun circuits—using Schrader Couplers, Hose and Automatic Hose Reels—take little space, yet put compressed air right at your fingertips.

They're economical—they have few moving parts. And replacement parts, when and if needed, are easily installed.

They're versatile—with nine interchangeable noses—both fixed and adjustable—that fit all three standard-type guns, you can't think of a blow-gun application that Schrader can't meet.

It's easy to find out for yourself what a wide selection of blow guns is in the complete Schrader Line of air control equipment. Write today—or, if you prefer, fill out the coupon below.

Schrader

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SPECIAL ADJUSTABLE NOSES

VARIOUS STANDARD NOSES

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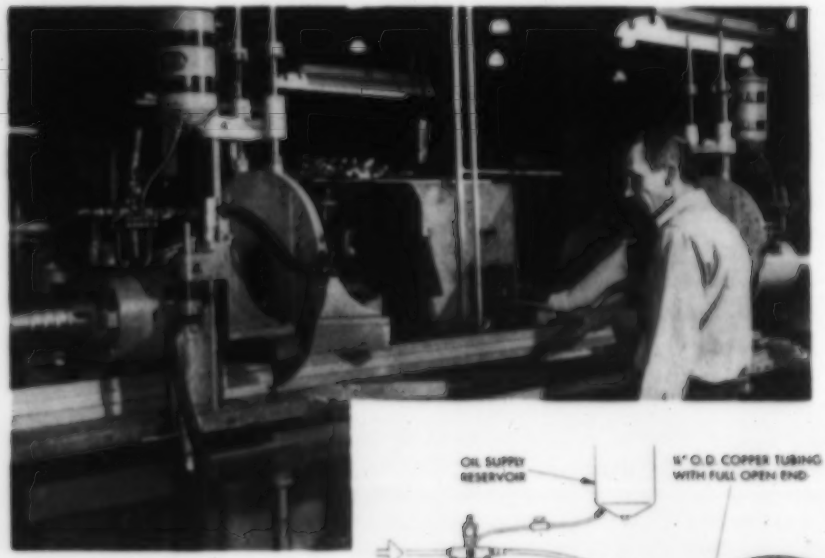
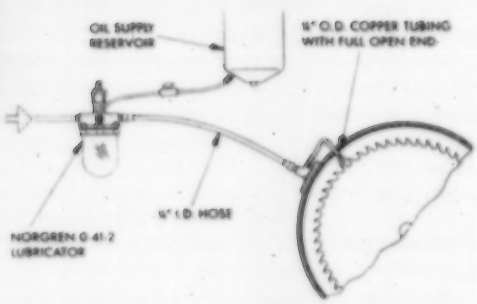
increases saw blade life 20 times
AT ALUMATIC CORPORATION of AMERICA

This prominent manufacturer of aluminum storm doors and windows uses Norgren Oil-Fog Lubrication on 16" circular saws for cutting to length extruded aluminum bars and shapes. The extrusions are 2½" to 4" wide and are generally stacked 3" to 4" high for simultaneous cutting.

Saw blade life expectancy was approximately 8 hours with the previous manual lubrication system, and burrs at the cut ends were excessive. With Norgren Oil-Fog Lubrication for each saw blade, the blade life has been increased to 3 to 5 weeks. A manual operation has been eliminated. Smoother cuts are obtained, burrs practically eliminated.

The Alumatic Corporation uses Norgren lubricators exclusively for the lubrication of pneumatically operated equipment.





A ¼" Norgren lubricator is used to lubricate each saw blade. The lubricant is a specially compounded cutting oil used at the rate of 3 fluid ounces per hour per blade. A cam-actuated spring loaded valve permits continuous spray application for heavy cuts and intermittent application on light cuts

For complete details on this Norgren Oil-Fog application, write for Norgren Blueprint No. 122, or phone the Norgren representative listed in your telephone directory, classified section under Norgren Pneumatic Products.

C. A. Norgren CO.
3442 So. Elati, Englewood, Colo.

Stress Relief

OUR now-retired sage, J. P. Henderson, is not beyond preaching a sermon for the benefit of those of us who haven't learned as long. Perhaps he has a point:

The Group Approach

"He travels fastest who travels alone." Kipling said it years ago but he was not speaking of engineering or scientific development.

The truth of the matter is that most developments these days are the result of group action. Patents with one man's name attached may identify only the leader or principal contributor to an idea on which a dozen men gave some assistance.

"If you have one dollar and I have one dollar, we each have one dollar. If you have an idea and I have an idea and we reveal them to each other, we each have two ideas."

If I knew who wrote that I would give him credit for a bright idea. It illustrates very succinctly the advantage of getting group action on a problem.

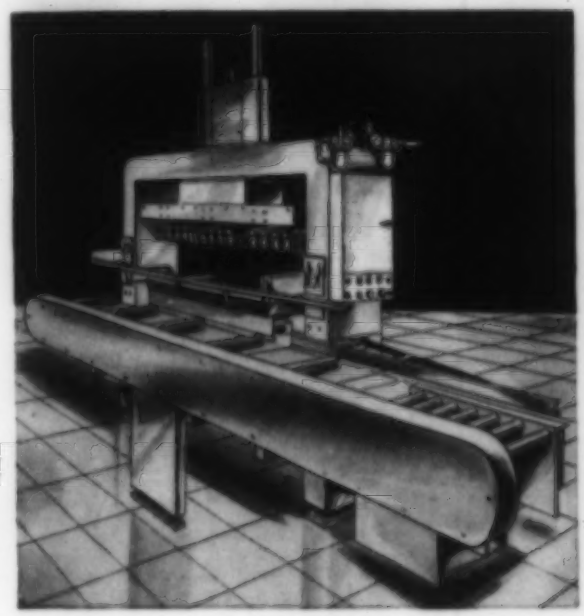
But what does group action mean to you as an individual? It requires that you be capable of working *with* a group. It implies an ability to get along with your associates. It implies (sometimes) patience with lesser minds. And it may require a certain amount of conformity with the conventions of your crowd.

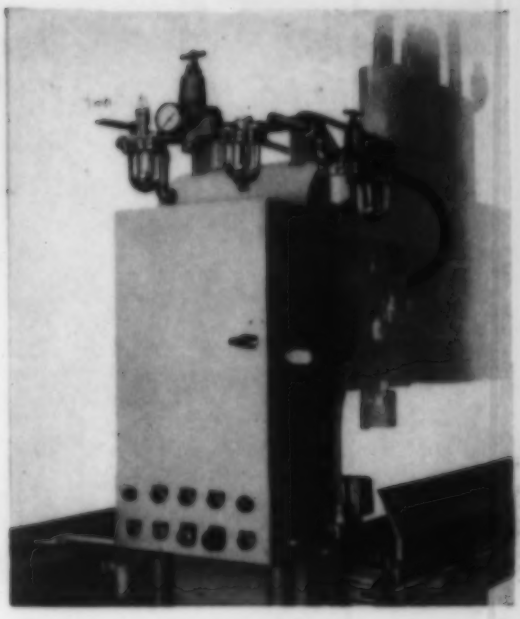
Now all of this can be a blessing or a curse to you as a personality! It's a matter of degree. And it's a question that each individual is going to have to answer for himself, usually while he is young enough to be pliable.

Conforming to the crowd, so that one is an effective worker on a technical team, can have some serious implications. Sam Levinson pointed out in one of his broadcasts that kids in kindergarden

Norgren PRESSURE REGULATORS

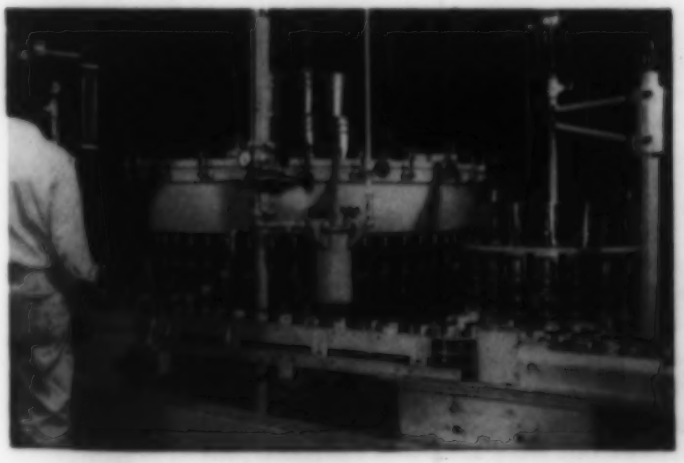
for accurate control of automatic machines





NEW-MATIC UNCASER This machine automatically removes empty bottles from cases at a maximum rate of 432 bottles per minute. Six double-acting air cylinders do the work. Accurate air pressure control is provided by three Norgren Pressure Regulators.

Dependable air line filtration and lubrication are provided by Norgren transparent bowl filters and lubricators. For complete details, write for Norgren Blueprint No. 123



CANNING MACHINE

This beverage canning machine at White Rock Canning Company, Denver, Colorado, uses a Norgren ½" Pilot-Controlled Pressure Regulator to control air pressure in the reservoir. Extreme accuracy of reservoir pressure is necessary to provide consistency in filling cans to a predetermined level.

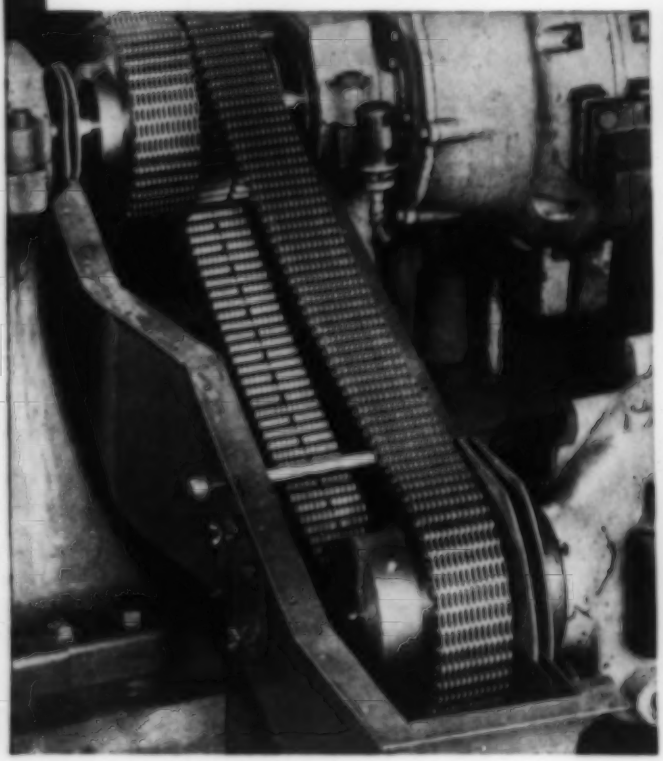
You, too, can have dependable pressure regulation with Norgren quality regulators.

A Complete Line of Pressure Regulators
NEARLY 400 STANDARD MODELS
...plus many others designed to meet specific job requirements.

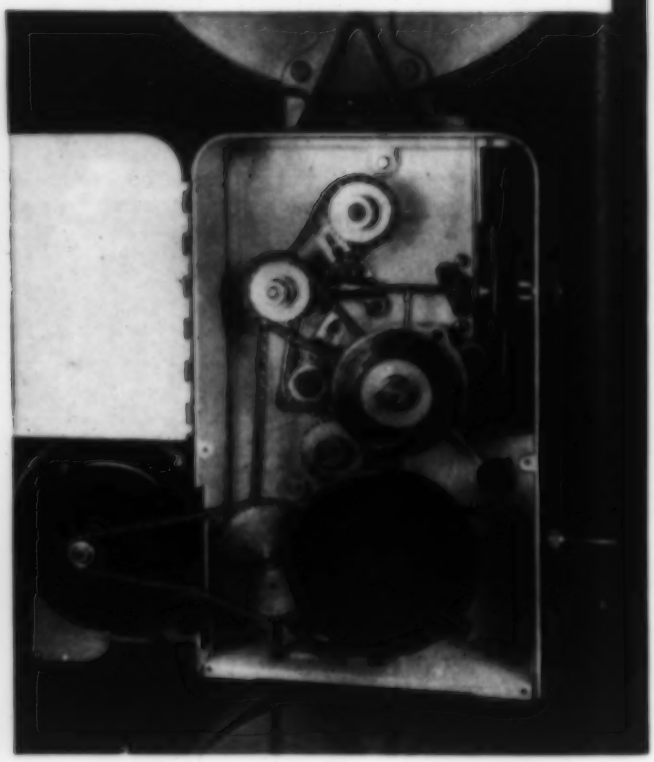
Write for complete data on Norgren Regulators or phone the Norgren representative listed in telephone directory classified section under Norgren Pneumatic Products.

C. A. Norgren CO.
3442 So. Elati, Englewood, Colo.

For high linear speeds...



For precise timing...



No other drive does these jobs... and many more... like

Link-Belt Silent Chain

FROM transmitting high horsepowers at high speeds ... to synchronizing sound and film in a motion picture projector—Link-Belt Silent Chain has proved its superiority for a wide range of drives. Better than 98% efficiency is maintained throughout its long life —frequently 20 to 30 years or more. Positive tooth-to-tooth action provides constant ratio for full productive capacity.

And silent chain is just part of the complete Link-Belt line. You can choose from all types and sizes of cast, combination, forged and fabricated steel, roller or silent chains—with matching sprockets. Your assurance of the *right* chain for your job.

For the complete story on silent chain drives, get Book 2425. And for facts on the complete Link-Belt chain and sprocket line, send for Catalog No. 950.

LINK-BELT

CHAINS AND SPROCKETS

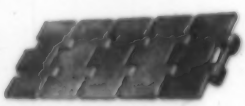
LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.

No ONE chain serves every purpose - - get the RIGHT one from Link-Belt's *complete* line

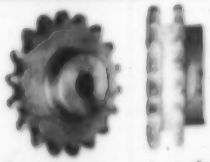
Precision Steel Roller Chain for moderate speed drives and conveyors. Available in single and multiple widths—¼ to 3" standard pitch, 1 to 3" double pitch.

LXS Steel Chains, with offset or straight sidebars, are made to close tolerances. Ideal for rugged drives, conveyors.

Detachable Link-Belt chains, available in steel, malleable or Promal, for light-strength drives and conveyors.



S-815 Flat-Top Chain—easy to detach and keep clean — one of complete line for carrying bottles, cans, cartons, cases, etc.



Complete line of single and multiple width cut tooth sprockets as well as a wide range of cast tooth sprockets.

nowadays bring home report cards with grades in "Social Science"! All that a good grade implies is that your angel doesn't clobber his classmates over the head. But this typifies the emphasis all along the educational process of teaching the young to conform.

If your actions conform outwardly with all of your group, through your formative years, is it likely that this also channels your thinking along completely conventional lines? Does it stifle original thinking? Is a development group, trained through all of their lives to observe current *mores* likely to produce a startling new idea?

I don't know the answer. I do know that I preferred not to put up with the unconventional, sloppily dressed Joe College, or the erratic almost-genius who never followed routine. And I suspect that most engineering executives would feel the same way. All of which is in favor of enough conformity so that a trained person can fit into group action.

Yet, as an old man, I can still remember some of the erratic screwballs that operated in the technical field in earlier days. Eccentric characters, colorful and full of surprises, many of them made useful contributions to technical progress and incidentally, money for themselves. Practically none of them worked *with* anyone. Operating as lone wolf inventors, or running little shops, they had helpers; but these were *employees*, not associates. They could not operate in harness and conventions meant little to them.

Our changing industrial picture provides little place for this type of character. Out of those that I knew in my younger days one especially stands out. We called him "Boundary Bill" and he deserves to live a little longer in technical memory. Perhaps I might write about him—sometime.

I'm sure that, as a boy, he clobbered all of his classmates, regularly.

—J. P. HENDERSON

"Old men are fond of giving good advise to console themselves for their inability to give bad examples."—LA ROUCHEFOUCAULD

FLEXON METAL HOSE *Design Briefs*

Vibration and Motion Problems in Gas Furnace Connections Solved with Flexon Metal Hose

FLEXON
The Complete Line for the Designer

REX-WELD corrugated metal hose in steel, bronze and alloys; sizes 3/16" through 24", I.D.; for burst pressures to 12000 psi.

REX-TUBE interlocked, square locked and double groove type hose and tubing in steel, bronze, stainless steel and other alloys; sizes 3/16" through 12", I.D. for low and moderate pressures and for use as conduit, ducting, exhaust, protective armor, etc.

DESIGN GUIDE No. 147 gives basic specifications and application data for Flexon Metal Hose. Write for your copy, today.

Gas fired furnace design presents a two-fold problem to the design engineer —vibration and thermal expansion.

However, both problems were solved simultaneously by Babcock & Wilcox designers in the furnace illustrated above. All of the many necessary connections were made with Flexon Rex-Weld corrugated metal hose.

Rex-Weld is ideal for services of this type because it is all-metal with no packing. It has the necessary flexibility combined with the ability to withstand high temperatures and high pressures. For all connections involving vibration, flexation, misalignment or expansion, specify Flexon Metal Hose. For specific recommendations send an outline of your requirements.

Flexonics *Corporation*
CHICAGO METAL HOSE DIVISION
1339 S. THIRD AVENUE • MAYWOOD, ILLINOIS
FORMERLY CHICAGO METAL HOSE CORPORATION

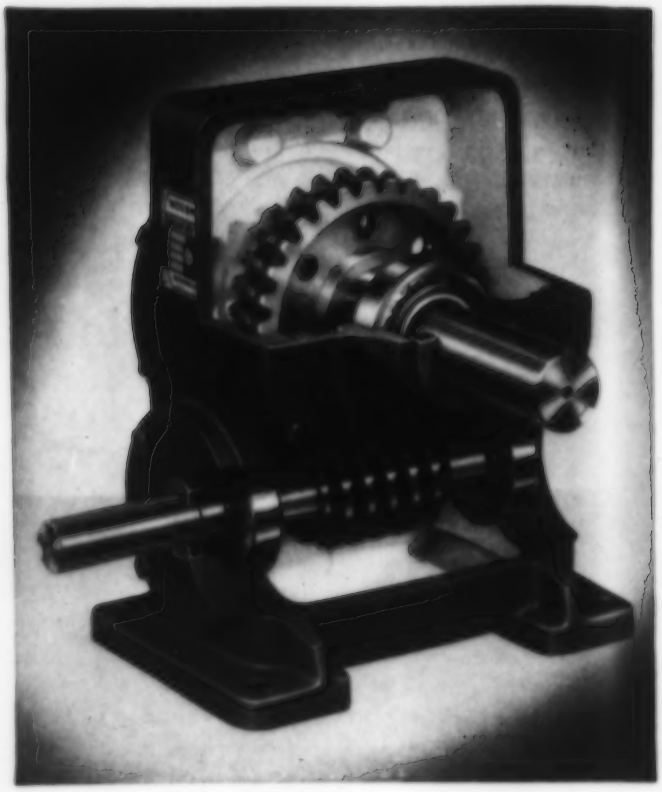
Flexon identifies products of Flexonics Corporation that have served industry for over 53 years.

Manufacturers of flexible metal hose and conduit, expansion joints, metallic bellows and assemblies of these components.
In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

WINSMITH SPEED REDUCERS

"C" SERIES

New Design . . . Brings New Economies



Here's how to get more for your speed reducer dollars! Specify the new "C" Series by Winsmith. This complete, newly designed line achieves a new high in compactness that simplifies design problems and helps you streamline your equipment.

INCREASED RATED HORSEPOWER AND TORQUE OUTPUT plus increased operating ruggedness are now available to speed reducer users in this new "C" Series. A total of 108 models in this series, including both double and single reduction units, has been added to the regular Winsmith line.

INCREASED OVERHUNG LOAD CAPACITY—achieved thru a combination of stronger shafts and larger, stronger tapered roller bearings.

INCREASED THERMAL CAPACITY—unique design of the housing gives greater heat radiating surface area without increasing overall size. The housing meets the most rigid principles of strength and provides a sturdy, vibrationless mounting.

• Horsepower and ratio range of "C" Series units and other reducers in the Winsmith line are given on the opposite page. The completeness of this line provides you with "one-source" —Winsmith — for all your speed reducer requirements.

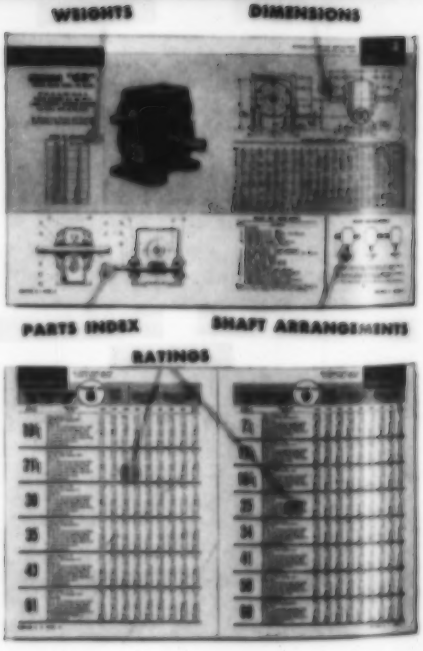
IF YOU HAVE A SPECIAL SPEED REDUCER PROBLEM, our Engineering Department or field staff of Sales Engineers can recommend the most economical solution.

WINSMITH . . . the most complete line of SPEED REDUCERS from a single source

For complete Engineering Data request Catalog No. 155

FACTS AT YOUR FINGERTIPS . . .

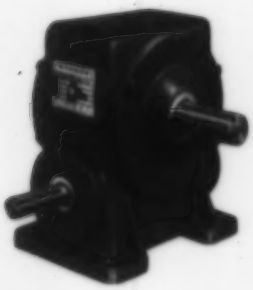
• Catalog No. 155 is as new in design and working convenience as the speed reducers it describes. Arrangement of engineering data gives you all selection information on each model of reducer without turning a page. Saves hunting and thumbing . . . *saves time.* Sectionalized for ease in locating the type of reducer most suitable to the application. For added reference value, it contains a General Engineering Section that serves as a Handbook for solving speed reducer application problems. When requesting a copy, specify Catalog No. 155.



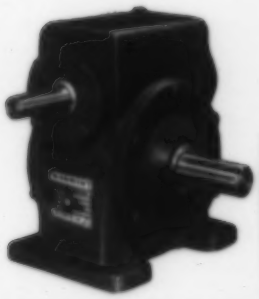
WINSMITH, INCORPORATED
18 Elton Street
Springville, (Erie County), N. Y.

SINGLE REDUCTION WORM GEAR TYPE SERIES CB, CT, CV

14 Sizes — .01 hp to 34 hp
Ratio Range — 5:1 to 77:1
Maximum Output Torque 142 to 34,767 in. lbs.



CB—WORM ON BOTTOM

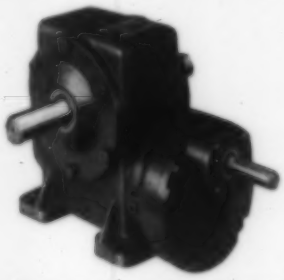


CT—WORM ON TOP

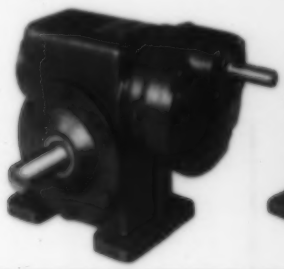
CV—VERTICAL

DOUBLE REDUCTION WORM AND HELICAL GEAR TYPE SERIES CBX, CTX, CVX

10 Sizes — .3 hp to 11.86 hp
Ratio Range — 42:1 to 231:1
Maximum Output Torque 1331 to 34,767 in. lbs.



CBX—WORM ON BOTTOM

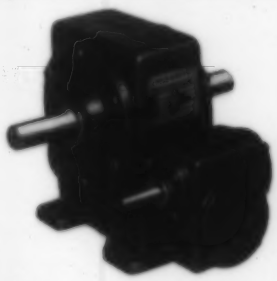


CTX—WORM ON TOP

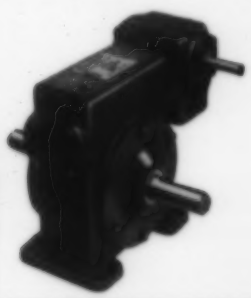
CVX—VERTICAL

DOUBLE REDUCTION WORM GEAR TYPE SERIES CBD, CTD, CVD

12 Sizes — .018 hp to 7.41 hp
Ratio Range — 60:1 to 4460:1
Maximum Output Torque 650 to 34,767 in. lbs.



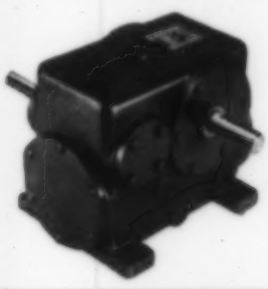
CBD—WORM ON BOTTOM



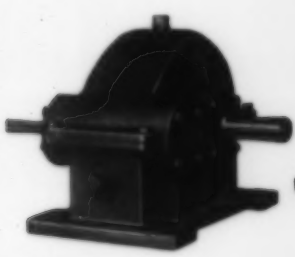
CTD—WORM ON TOP

CVD—VERTICAL

1. **DOUBLE REDUCTION WORM GEAR TYPE**
   9 Sizes — .006 hp to 7.319 hp
   Ratio Range — 25:1 to 3850:1
   Maximum Output Torque 146 to 34,290 in. lbs.
2. **SINGLE REDUCTION HELICAL GEAR HORIZONTAL TYPE**
   3 Sizes — .05 hp to 18.86 hp
   Ratio Range — 3.06:1 to 12.66:1
   Max. Output Torque 294 to 3682 in. lbs.
3. **TWO SPEED REDUCTION WORM AND SPUR GEAR TYPE**
   2 Sizes — .01 hp to 6.17 hp
   Ratio Range — 5:1 to 163:1
   Max. Output Torque 333 to 3089 in. lbs.



1. SERIES **DBI**

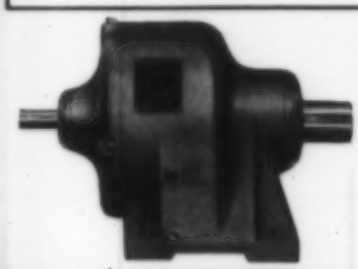


2. SERIES **700, 800, 900**

3. SERIES **TSR**

DIFFERENTIAL REDUCERS

.12 hp to 81.51 hp
Ratio Range 1.1:1 to 50,000:1
Maximum Output Torque 50 to 113,000 in. lbs.



HORIZONTAL

FLANGE MOUNTED

VERTICAL MOTORIZED

WINSMITH, Incorporated • *18 Elton Street, Springville, (Erie County) N. Y.*

LABOR RELATIONS ?

O. W. Churchman

PRESIDENT • CINCINNATI GEAR CO.

That phrase "Labor Relations" has always bothered me. Personally I think it's the most misleading phrase in our language. Labor, to me, means hard, back-breaking toil, perhaps like the galley slaves of old—now that was really labor! We at Cincinnati Gear prefer a phrase like "Craftsmen-Management Relations."

After all, the men who work in our plant *are* craftsmen—skilled craftsmen of the highest order. We are managing the business—our skilled craftsmen are turning out the perfect gears that are the lifeblood of our business.

These men are important—we strive at all times to give them the finest machinery and the most pleasant working conditions possible. Craftsmen who have been with us five years or more are covered by a pension plan, with retirement benefits up to 30% of their regular monthly pay; our suburban location means a cleaner and more beautiful plant; color experts decided what color paints would be most conducive to a pleasant atmosphere inside our plant.

Our efforts have not been in vain—for over thirty years, when virtually every company had so-called "Labor" problems, production and pleasant relations at Cincinnati Gear continued as in the past.

No, we don't employ laborers at Cincinnati Gear—they are, and always will be, "Skilled Craftsmen!"

THE CINCINNATI GEAR CO.

CINCINNATI 27, OHIO

"Gears — Good Gears Only"

CINTI

THE ENGINEER'S Library

Recent Books

Hydraulic Operation and Control of Machines. *By Ian McNeil;* 336 *pages,* 5¼ *by* 8½ *inches, clothbound; published by Ronald Press Co., New York; available from* MACHINE DESIGN, $7.50 *postpaid.*

This book discusses established methods of hydraulic drive, examines new developments and indicates future trends. Beginning with an explanation of basic principles of hydrostatics, it goes on to treat pumps and motors, valves and circuits, power-saving devices, etc. The book concludes with a study of the use of hydraulic machinery in machine tools, mining, agriculture, aeronautics, marine engines and lifting devices.

Other subjects covered in the 17 chapters include hydraulic fluids, seals, packings, pipes, pipe couplings, power transmission, forging presses, extrusion machines, deep-drawing and stamping presses, molding and die-casting machines, and operation, care and maintenance of hydraulic plant and equipment.

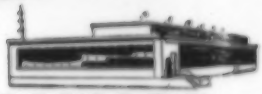
•

Testing and Inspection of Engineering Materials. *By Harmer E. Davis, professor of civil engineering, George Earl Troxell, professor of civil engineering, and Clement T. Wiskocil, late professor of civil engineering, University of California;* 447 *pages,* 6 *by* 9 *inches, clothbound; published by McGraw-Hill Book Co. Inc., New York; available from* MACHINE DESIGN, $6.50 *postpaid.*

This second edition develops a basis for preparation of specifications and a background for inspection of engineering materials. It points out the relation between properties of materials and means to measure them. It provides a general treatment of concepts and principles of materials testing, dis-

Silicone O rubber parts produced

by



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involving extreme temperatures

up to 500°F

down to -120°F

write today for details

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Mfg. Plants in Bedford, Ohio and Jasper, Georgia

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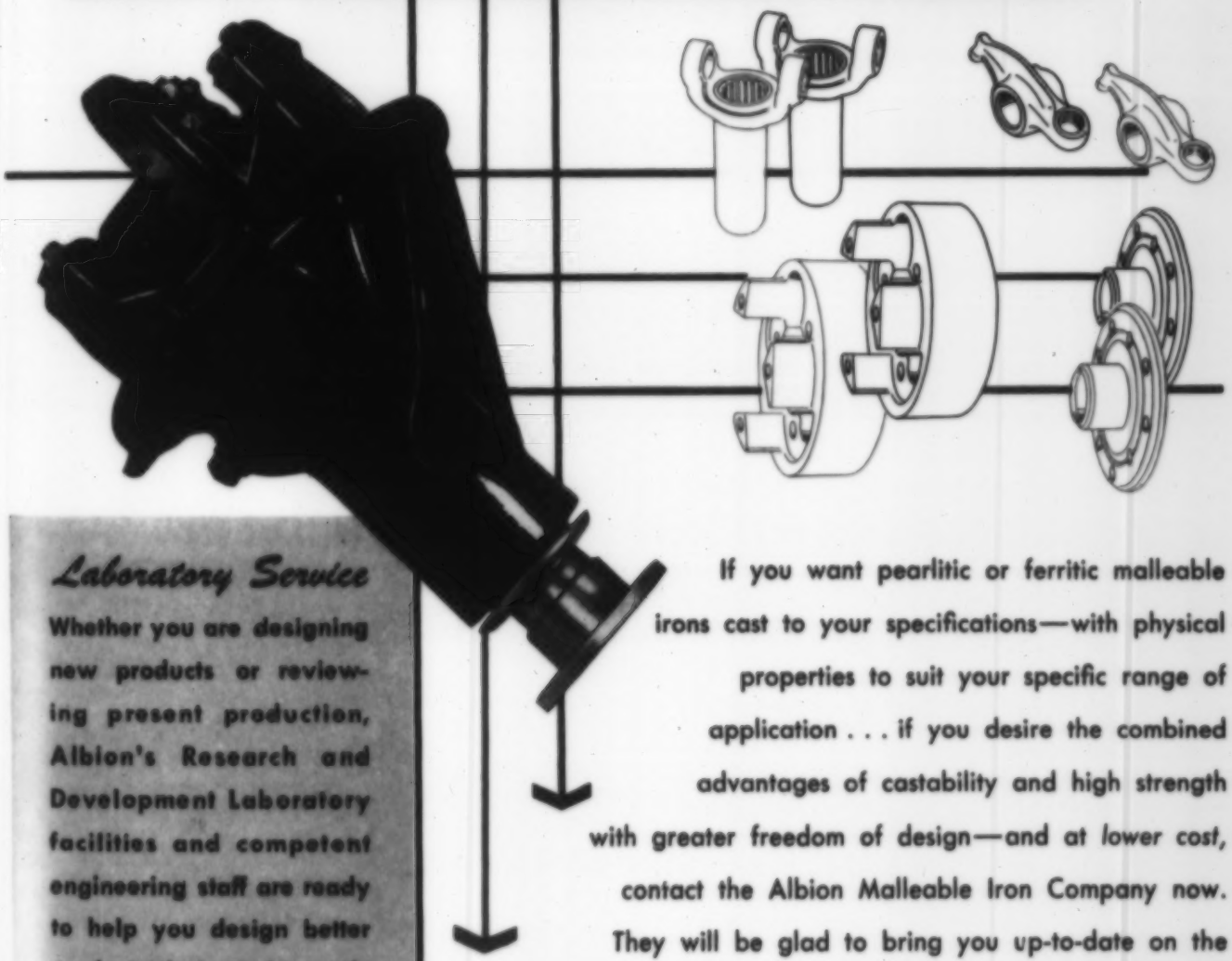
If you want to be certain



Laboratory Service

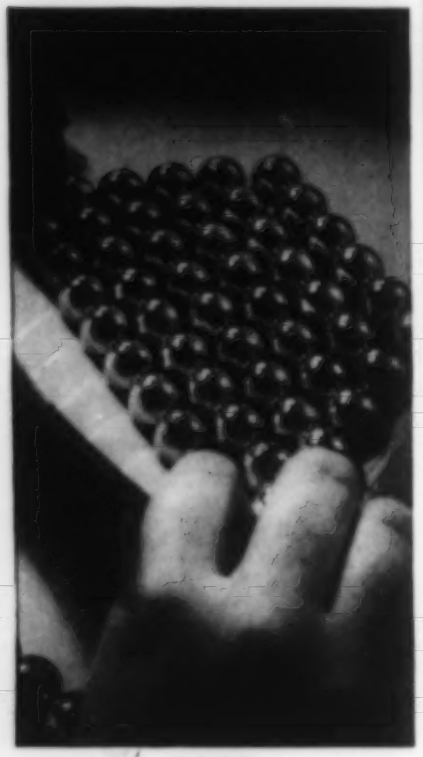
Whether you are designing new products or reviewing present production, Albion's Research and Development Laboratory facilities and competent engineering staff are ready to help you design better products that can be made at lower cost.

If you want pearlitic or ferritic malleable irons cast to your specifications—with physical properties to suit your specific range of application . . . if you desire the combined advantages of castability and high strength with greater freedom of design—and at *lower cost*, contact the Albion Malleable Iron Company now. They will be glad to bring you up-to-date on the rapid development in Albion's modern casting techniques which offer engineering advantages that are yours—*if you want to be certain.*

Remember . . . there is no engineering substitute for good, accurate, dependable castings!

ALBION MALLEABLE IRON CO.
ALBION, MICHIGAN

FOR
UNIFORMITY



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ABBOTT BALLS

In any given shipment of Abbott carbon steel Bearing Balls you'll find UNIFORMITY of size tolerances and sphericity. This is because Abbott production standards are geared to meet industry's most rigid requirements. Every Abbott Bearing Ball — *Deep Hardened and Tempered* for maximum shock resistance and load carrying ability — is a model of precision, unsurpassed for sphericity, size tolerance, depth of case and other essentials of fine carbon steel bearing balls.

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The Engineer's Library

cusses many types of tests in current use, describes testing equipment, and covers effect of variables on test results.

Subjects covered include general features of mechanical testing; measurement of load, length and deformation; static tension and compression tests; static shear and bending tests; hardness; impact; fatigue and creep tests; nondestructive tests; and analysis and presentation of data. Methods of conducting common tests are presented in a form applicable to most ordinary apparatus.

Various new procedures, testing machines and special testing devices such as microhardness testers are described. New types of nondestructive tests, including use of ultrasonics and penetrants for detecting defects, are discussed. Low-temperature impact tests and stress-strain relations are covered. A classified list of references is appended. A brief summary of properties of materials for use in estimating load schedules is also included.

•

Servomechanisms and Regulating System Design, Volume 2. *By Harold Chestnut and Robert W. Mayer, Aeronautics and Ordnance Systems Div., General Electric Co., 398 pages, 6 by 9 inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, *$8.50 postpaid.*

Covering both analytical and practical aspects of servomechanism design, this volume is devoted to needs of practicing designers and advanced graduate students. It presents information needed for rephrasing requirements of equipment users into terms of control system designers.

Chapter 1, on measurement techniques, stresses the importance of measurements before, during and after designing. Chapter 2 deals with influence of input characteristics on control system design. In Chapters 3 and 4 methods for selecting power and stabilizing portions of control systems to meet requirements of desired and extraneous input signals

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THE CLARE TYPE T
High Frequency
Impulse relay

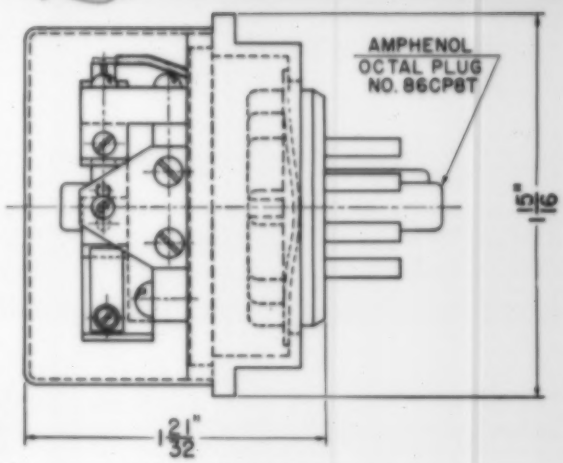
• Shown above with dust-tight cover removed (left) ready for mounting.

• Announcement of the CLARE Type T High Frequency Relay two years ago set off such a deluge of inquiries for samples and information that it is only just now that production facilities permit us to mention it again.

Originally designed for use in an analog computer, this relay is ideal for designs which call for a highly sensitive relay completely free from contact bounce and capable of billions of operations at extremely high speeds.

Pull-in time of this relay, for instance, is 120 microseconds. With dropout time of 100 microseconds, the relay follows up to 2500 cycles per second; aperiodic to 1000 cycles per second.

Manufacture of the CLARE Type T Relay, with its high speed, no bounce and other unusual characteristics, necessitated the development of entirely new techniques. It is built to extremely close tolerances, with a high degree of precision and fabricated under conditions of utmost cleanliness.



SPECIFICATIONS

MECHANICAL

Size: 1-15/16 in. dia. x 2-3/16 in. overall. Weight: 5 oz.

Mounting: Equipped with plug, to fit standard 8-pin octal socket.

Cover: Removable dust-tight cover.

Contacts:
- **Type:** Form A (s.p.s.t., normally open)
- **Material:** Platinum-iridium
- **Gap:** 0.0005 inch
- **Pressure:** 30 grams, min. (Coil energized with 50 ampere-turns)

Coil:
- **Type:** Single winding, bobbin-wound.
- **Wire:** Heavy formex.

ELECTRICAL

Operate Ampere-Turns: 8 to 20.

Release Ampere-Turns: 1 to 4 less than operate ampere-turns.

Nominal Ampere-Turns for High-Speed Operation: 16 to 40.

Speed of Operation: will follow 2500 cycles per second; aperiodic to 1000 cycles per second.

Operate Time: 100 to 180 microseconds.

Release Time: 60 to 120 microseconds.

Contact Bounce: None.

Contact Current Rating: 0.05 amp., max.

Contact Voltage Rating: 150 V., max.

Dielectric Strength: 500 V., rms.

Coil Resistance: up to 600 ohms.

Life Expectancy: 5 x 10^9 operations (determined by contact load).

TYPICAL CHARACTERISTICS

Coil Resistance: 135 ohms.

Coil Inductance: .35 Hy.

Operate Current: 10 to 12 ma.

Release Current: 8 to 10 ma.

Nominal Current: 40 ma., steady state; 20 ma., average.

Operate Time: 130 microseconds.

Release Time: 100 microseconds.

Energizing Circuit: Coil in plate circuit of vacuum tube with 300 volt plate supply.

For full information on the CLARE Type T Relay —or for consultation on any relay problem—see your nearest CLARE Sales Engineer or write C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: Canadian Line Materials Ltd., Toronto 13. Cable Address: CLARELAY.

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FIRST IN THE INDUSTRIAL FIELD

CLARE RELAYS

are discussed. Requirements of servomechanism amplifiers used to match stabilizing elements with power elements are discussed in Chapter 5. Chapter 6 is devoted to all ac servomechanism design. Chapters 7, 8 and 9 cover nonlinearities in control system design, including application and linearization of nonlinear elements.

•

Operations Research for Management. *Edited by Joseph F. McCloskey and Florence N. Trefethen; 433 pages, 6 by 9 inches, clothbound; published by Johns Hopkins Press, Baltimore, Md.; available from* MACHINE DESIGN, *$7.50 postpaid.*

Purpose of this book is to provide a comprehensive introduction to the science of operations research. Contributors to this volume include industrialists, engineers, physicists, mathematicians, economists and practicing operations researchers. It was developed largely from lectures presented during a seminar on operations research at Johns Hopkins University in 1952.

Part 1 of the book provides an overall look at the scope and history of operations research. Part 2 deals with methodology, including use of statistics, information theory, computing machines, linear programming and other allied techniques. Case histories make up Part 3, graphically demonstrating the wide variety of uses for the new science in planning industrial operations.

•

Form in Engineering Design. *By J. Beresford-Evans; 96 pages, 5½ by 8½ inches, clothbound; published by Oxford University Press, New York; available from* MACHINE DESIGN, *$1.70 postpaid.*

This book discusses and illustrates techniques for giving products a pleasing and durable appearance. It deals with such practical aspects as why certain shapes look more satisfactory than others, how to treat large surfaces or significant details, and how to make the best of difficult and ugly accessories. It emphasizes guiding principles rather than rules, and presents factual examples of design.

•

Calculation of Change Gear Ratios. *By Eric H. Wang, research engineer, U. S. Air Force; 117 pages, 8½ by 11 inches, ringbound, paper covered; available from Eric H. Wang, 601 Monroe Drive, Xenia, Ohio, $3.50 per copy.*

This book presents a method of finding desired change gear ratios by using suitable combinations of whole numbers. Logarithms or advanced mathematics are not required. A brief introductory text gives method of calculation and improvement of gear ratios, followed by several examples. Remainder of the book consists of factor tables used in calculating gear ratios, and tables for improvement of ratios. The factor tables of numbers between 10,000 and 100,000 contain prime factors between 2 and 97, and therefore allow choice of gears with a number of teeth equal to those prime numbers and their multiples.

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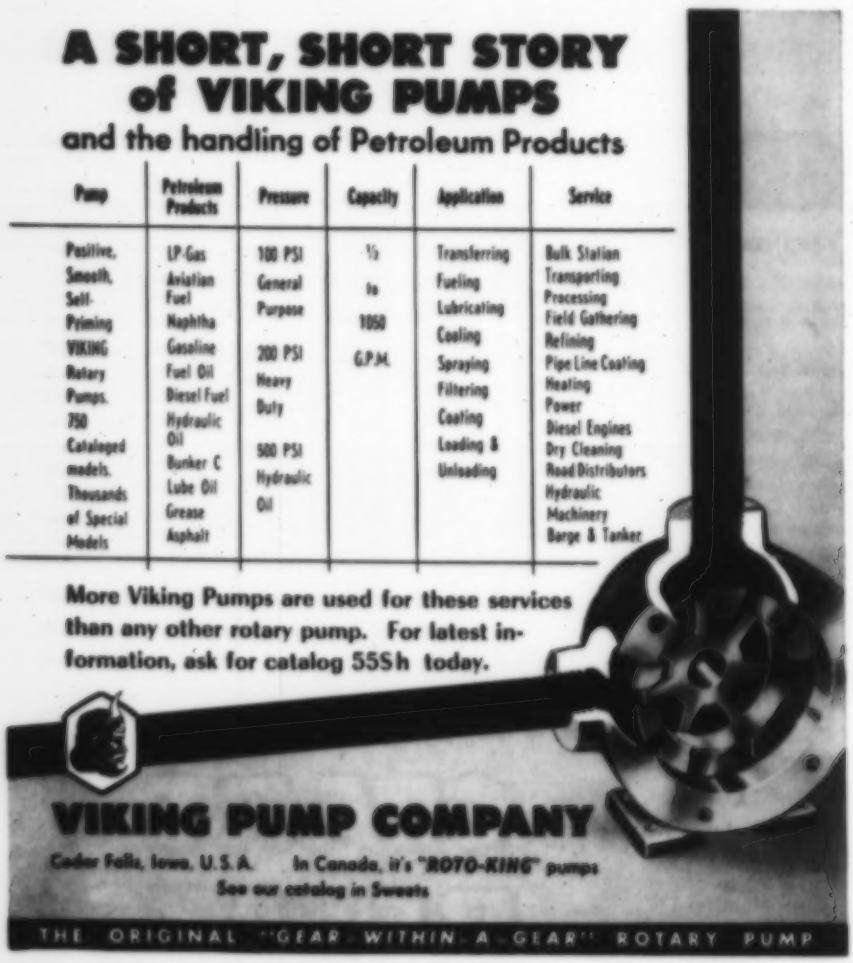

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New Standards

Tentative Specifications for Mild Steel Arc Welding Electrodes. *A233-55T; 24 pages, 8½ by 11 inches, paperbound; available from American Welding Society, 33 W. 39th St., New York 18, N. Y., 40 cents per copy.*

These specifications cover lightly coated and covered metal arc-welding electrodes for welding of carbon and low-alloy steels of weldable quality. Standard properties and performance requirements of the relatively new iron powder electrodes are given for the first time.

Association Publications

Engineering Alloys. *By Norman Woldman, consulting metallurgical engineer; 1052 pages, 6 by 9 inches, clothbound; published by and available from American Society for Metals, 7301 Euclid Ave., Cleveland 3, O.*

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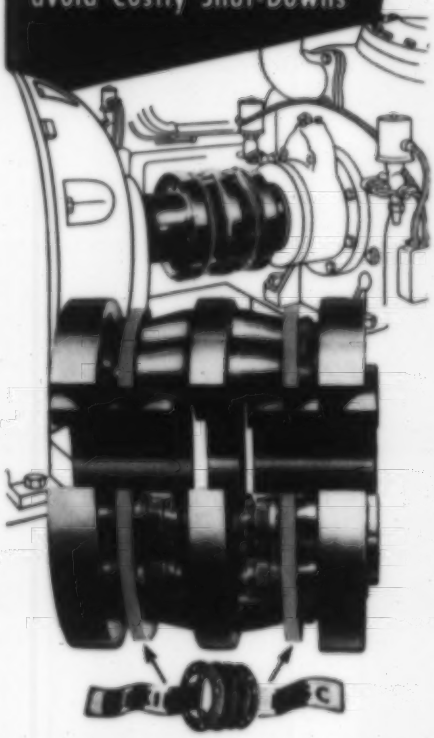

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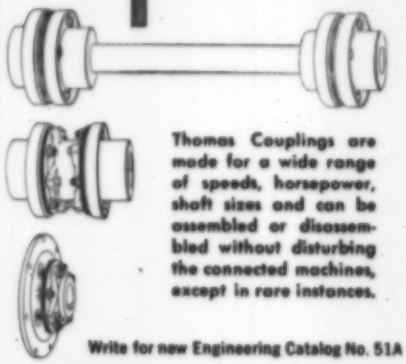

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In this third edition, 19,280 alloys are listed with alloying data and manufacturer's name. Included are an alphabetical list of alloys, tradenames, composition, properties, uses and manufacturer's designation. Manufacturers are listed alphabetically with address and alloys they produce. Definitions, conversion tables and other information are included.

•

Proceedings of the National Electronics Conference, 1954, Volume 10. *872 pages, 6 by 9 inches, clothbound; available from National Electronics Conference Inc., 84 E. Randolph St., Chicago 1, Ill.,* **$5.00** *per copy.*

This book contains the 86 technical papers presented at the 1954 National Electronics Conference. These papers cover electronic research, development and application of antennas, circuits, communications, computers, electron tubes, engineering management, instrumentation, magnetic amplifiers, materials and components, microwaves, radar, servomechanisms, solid state devices and television.

Also included is a cumulative index by subject and author of all technical papers presented during the first ten years of the National Electronics Conference.

•

National Convention Transactions, 1955, American Society for Quality Control. *761 pages, 6 by 9 inches, paperbound; available from American Society for Quality Control Inc., Room 563, 50 Church St., New York 7, N. Y.,* **$3.50** *per copy.*

Several papers applying to machine design appear in this book of transactions of the Ninth Annual Convention of ASQC. They include discussions of effect of quality control on standards, redesigning for production, evaluating performance of electronic equipment, and use of quality control in new product development.

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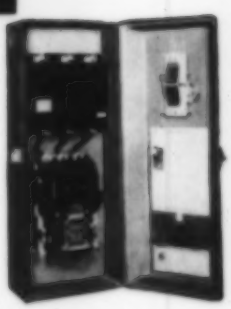
CONTROL COMPONENTS



INDIVIDUAL MOTOR CONTROL

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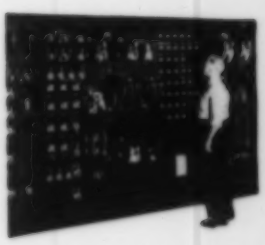
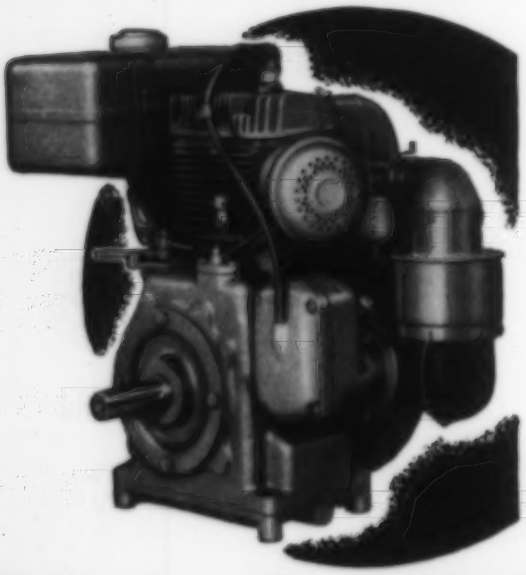


CONTROL SYSTEMS



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Model ACN, 5½ H.P. Single Cylinder HEAVY-DUTY Air-Cooled ENGINE

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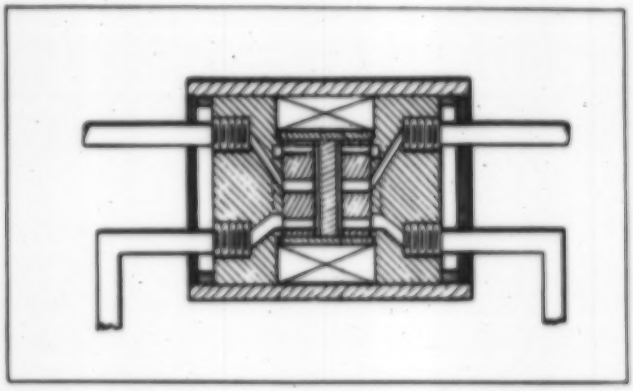
NOTEWORTHY Patents

Magnetic Fluid Valve

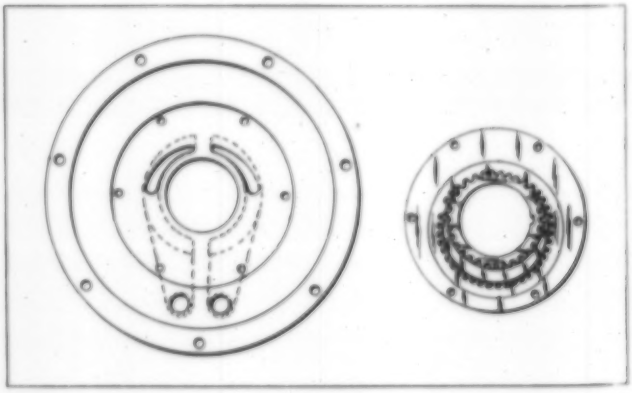
Rate of flow of "magnetic" fluids can be controlled by a valve with no moving parts. Solenoids enclosing the fluid lines are energized to "freeze" the magnetic fluid particles and thus restrict the



flow through the lines. Precision control of hydraulically-actuated mechanisms may be obtained with the device by varying the voltage applied to the coils. *Patent 2,692,582 assigned to North American Aviation Inc. by R. L. Curci and R. E. Smith.*

Reversible Gear Pump

Direction of fluid flow through a gear pump can be reversed by turning the seal plate and housing



a predetermined number of degrees in relation to the cover. Design of the pump is such that ports and flow passages are automatically aligned in either direction of flow. When direction of flow is

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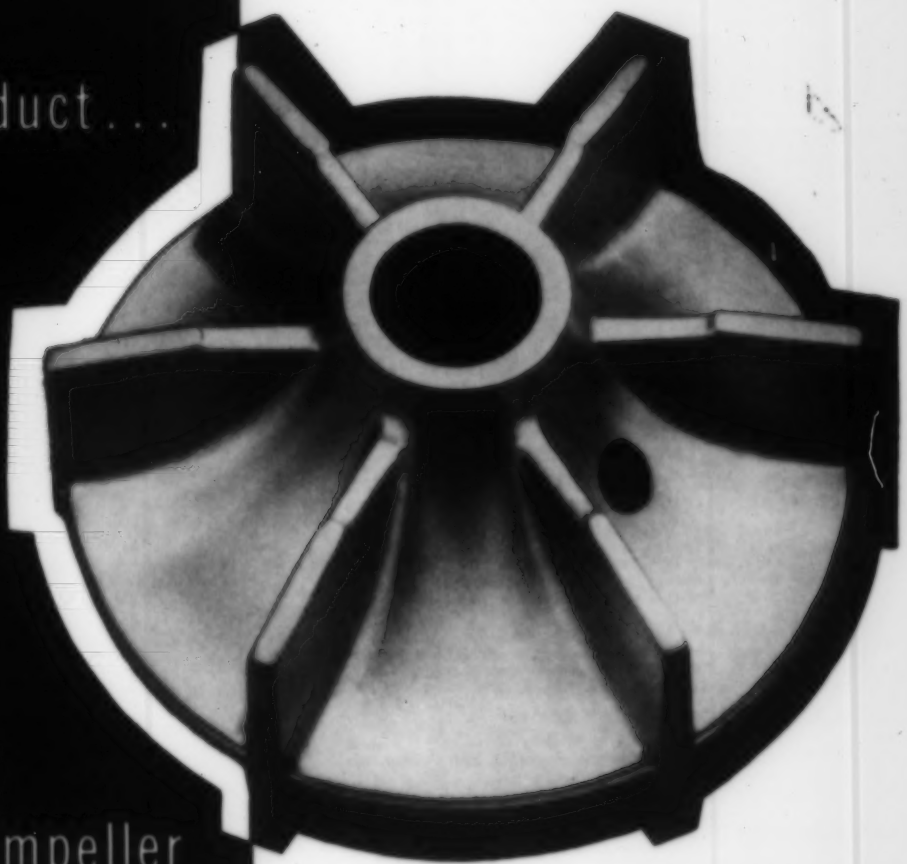

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Formerly produced as sand castings, these impellers now give better results because they're forged from "603" high strength bronze by the Mueller Brass Co. Said to be "right for the job and far superior to the old cast impellers", these forgings bring greater efficiency and longer life to the diesel engine water pumps in which they are installed. This tough "600" series alloy is readily forgeable, possesses remarkable resistance to corrosion, and has fine bearing qualities. Uniformity is excellent, due to the closer dimensional control of the forging process, and surface finish is noticeably smoother. This is another case where Mueller Brass Co. forgings have greatly improved a product . . . why not let our engineers show you the many advantages of using forgings.

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Model ES4-KM2
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ELIMINATES INTERLOCKING SWITCHES AND COMPLICATED ACTUATING DOGS

Ideal for pulsing solenoid valves on air-hydraulic controls, sequencing circuits, etc., because it allows other controls to reverse or operate the same circuit. Switch sends a short electrical impulse and then switches itself out of the circuit.

GIVES MORE DEPENDABLE CONTROL

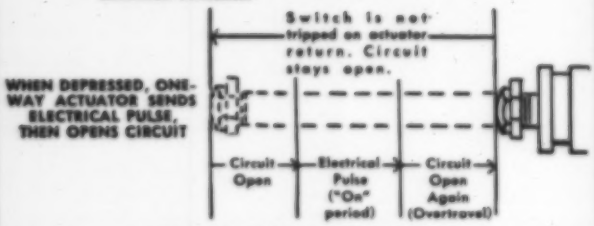
Switch replaces timers, relays, and troublesome one-way dogs to simplify circuits — cuts chances for failure. No delicate adjustments.

LOWERS COST OF CONTROL CIRCUITS

Impulse switch costs less than complicated control devices it replaces. Fewer switches are required for sequencing. Simple mounting.

SPEEDS UP AUTOMATIC OPERATION

Automatic machines can run faster because cycles can be more closely sequenced. There's no delay due to timer tolerances or extra machine motions to actuate interlock switches.


Switch is not tripped on actuator return. Circuit stays open.
WHEN DEPRESSED, ONE-WAY ACTUATOR SENDS ELECTRICAL PULSE, THEN OPENS CIRCUIT
Circuit Open
Electrical Pulse ("On" period)
Circuit Open Again (Overtravel)

SPECIFICATIONS

UL rated at 10 amps/125v AC Movement Dif. 0.020"
Operating Force 3½ lbs.

Model No.	Overtravel	"On" Period (inches of actuator travel)
ES4-KM1	3/8"	1/16"
ES4-KM2	5/16"	1/8"
ES4-KM3	1/4"	3/16"
ES4-KM6	1/16"	3/8"

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Specify Model Wanted—Discounts on Quantity Purchases

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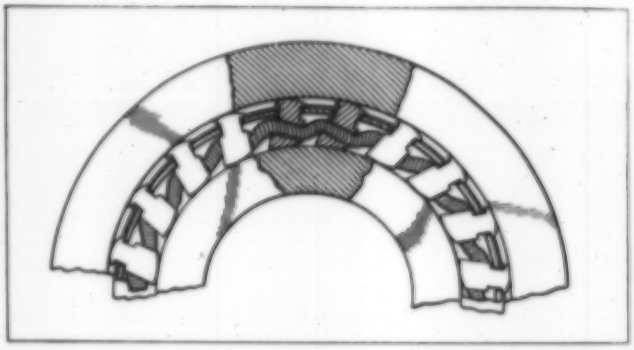
Noteworthy Patents

changed, an arrangement of openings in the seal plate is reversed with respect to the position of mating ports in the cover. Thus, fluid flow in one direction can be maintained, regardless of the direction of rotation of the rotor, by merely adjusting the seal plate. *Patent 2,694,367 assigned to Paragon Gear Works Inc. by R. W. Seavey.*

Sprag Clutch

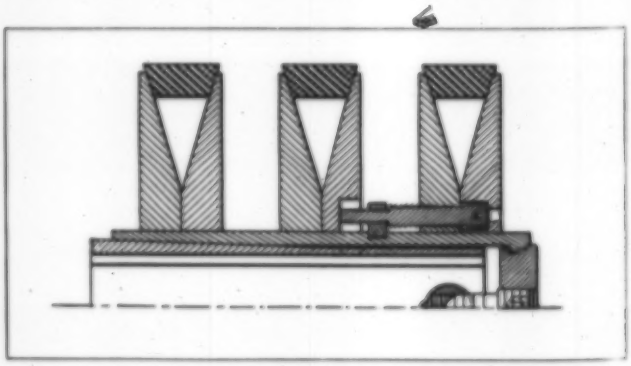
One-piece, sheet metal mounting cage in a sprag type clutch is designed to facilitate assembly and disassembly. Open-ended slots in the cage accom-



modate grooves in the gripper elements and act to limit tilt and radial movement while also permitting the grippers to be readily slipped on or off. A retaining spring, threaded through the grippers, is mounted inside the cage for protection from mishandling. *Patent 2,693,868 assigned to Borg-Warner Corp. by C. E. Swenson.*

Variable-Pitch V-Belt Sheave

Ratio of multiple V-belt drives may be adjusted by varying the effective diameter of the sheaves with a differential adjusting screw. One set of sheave flanges engages a coarse threaded portion of the ad-



justing screw while the opposite flanges are connected to head of the screws. In addition, a fine threaded portion of the adjusting screw engages a fixed nut so that the screw moves axially when rotated. As a result, both sets of sheave flanges move in opposite directions upon rotation of the screw.

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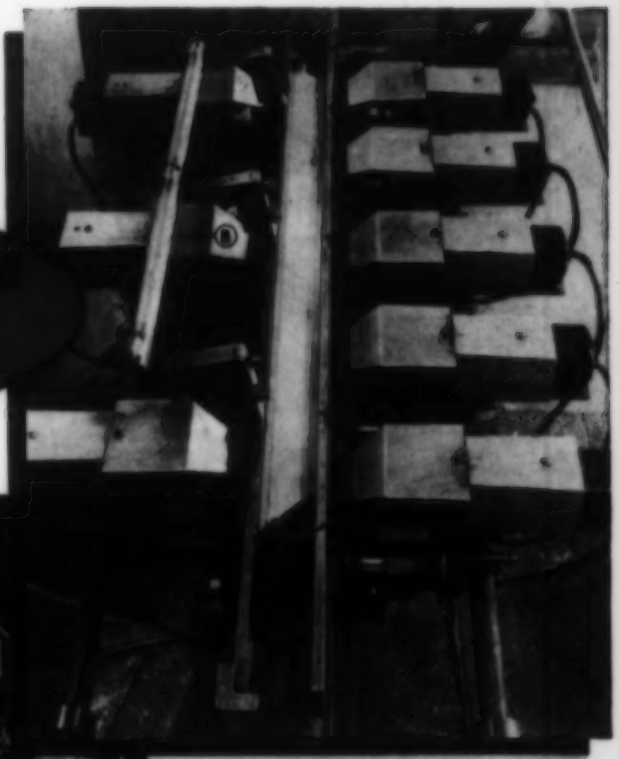

Here's how *Rylock* did it:

Rylock air-actuated multiple drill automatically drills all holes on both edges of aluminum screen door frame piece in one operation. Independently-powered heads are movable, will accommodate all models of doors manufactured.

Operator places piece in fixture, depresses MODERNAIR foot valve C; MODERNAIR cylinder D advances and retracts all drills. Entire cycle requires 10 seconds.

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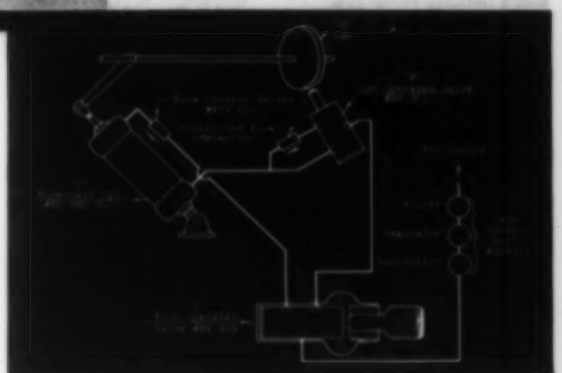
A typical Rylock-Modernair application is shown here. We have many others on file that may give you some practical ideas on how to cut costs with MODERNAIR air or hydraulic cylinders and control valves. Why not write for your copy of the MODERNAIR Applications Manual *NOW?*

See our display — Booth #959, National Metal Exposition, Philadelphia Convention Halls, Oct. 17 thru 21.



Foot valve advances cylinder D rapidly until cam operates valve F which introduces flow control valve G into circuit. This slows advance during drilling cycle; on completion of cycle operator releases foot valve, cylinder D retracts drills.

[redacted]RPORATION

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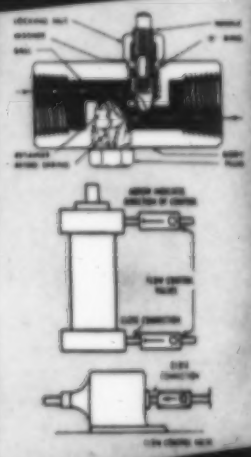
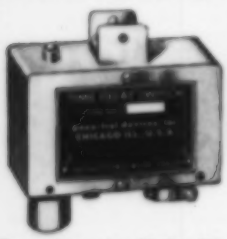
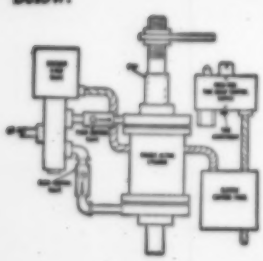


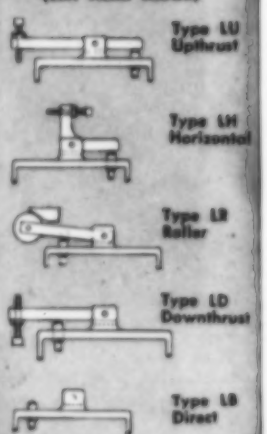
TIME DELAY CONTROL SWITCH FOR PRECISE DELAY OF WORK CYCLE



Provide controlled adjustable time dwell of solenoid operated air or oil supply valves. Range between ¼ and 60 seconds in 20 to 1 ratios. Compact—simple—foolproof—rugged Easily mounted on machine. Available for various types of actuation. Typical diagram below.



For Any Type Actuation Left or Right Hand (Left Hand Shown)



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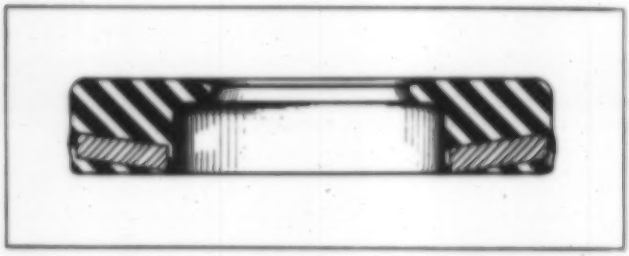
Components for Automation
1416 N. Keating Ave. Chicago 51, Ill.

Noteworthy Patents

thus changing the effective diameter. Pitches of the coarse and fine threaded portions of the adjusting screw are designed so that V-belt center lines are not shifted when the sheave diameters are changed. *Patent 2,697,947 assigned to Dodge Mfg. Co. by D. Firth.*

Leaktight Shaft Seal

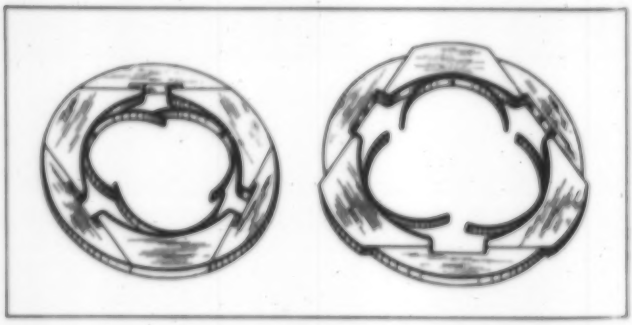
A dished metal washer molded inside a rubber ring offers a flexible fluidtight seal for rotating shaft assemblies. Stripping of the rubber from the washer is prevented by the dished washer construction which



provides maximum molding surface and acts to reinforce and support the rubber ring. Because of its high flexibility, the seal is effective even if the shaft is not running true. *Patent 2,697,623 assigned to National Motor Bearing Co. by E. D. Mosher.*

Wear-Compensating Piston Ring

Circular ring segments with bowed spring strips on their inner surfaces form an expansible piston ring. In operation, the springs, which are mounted to metal backing strips on the segments, keep the



segments in contact with the cylinder walls, thus automatically compensating for wear. Expansion of the rings is limited by groove stops to prevent scoring of the cylinder walls by the backing strips. *Patent 2,696,414 assigned to Joy Mfg. Co. by W. E. Green.*

Pressure Operated Seal

Fluid pressure acting on a high-temperature sealing ring for turbine or similar rotors forces the seal into engagement only when the turbine is operating. One edge of the seal is pressed into a chamber that is ported to the upstream side of the turbine. Operating pressure within the chamber forces the re-

silient seal against a conical surface of the turbine diaphragm. As a result, the seal is forced downward into sealing engagement with the turbine rotor. When the machine is not operating, pressure does not exist and the seal is free to move away from the rotor. Seizing of the seal on the rotor due to differential contraction of the turbine parts when the machine is cooling is eliminated, thus avoiding possible damage to the seal. *Patent* 2,686,657 *assigned to United Aircraft Corp. by A. Kalitinsky.*

Blind Fastener

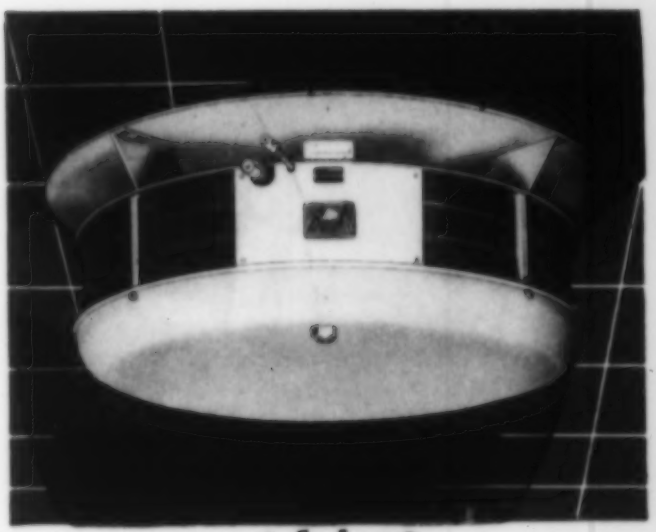
A formed rod shank sliding in a headed hollow sleeve is the basis of a blind fastener that is stressed in tension when locked in position. A snap ring is installed on the head end of the rod shank and prongs, mounted at the other end, extend back along the shank surface end. After the sleeve and shank assembly are inserted in mating holes in the parts to be fastened, the shank is moved outward, causing the prongs to contact the back of one of the parts and bend. This action places the shank under tension and the snap ring locks into place when the desired holding force is attained, thus holding the fastener and parts firmly in place. Fastener tension and length may be readily adjusted to meet different mounting requirements. *Patent* 2,697,375 *assigned to Northrop Aircraft Inc. by A. G. Brisack.*

Antibacklash Mechanism

A series of multiple magnetic poles, spaced concentrically around a rotating shaft, are utilized to create a small drag load on the shaft. In a gear train, this drag load acts to maintain pressure between the meshing gear teeth and thus prevent backlash. The magnetic circuit may also be made of one piece of magnetic material having teeth magnetized in opposite polarities. In a modification of the invention, the magnetized teeth or poles are on the rotating element and are surrounded by a ring of magnetic material. *Patent* 2,696,655 *assigned to American Viscose Corp. by Camiel de Brabander and Frank Rudbarg.*

Compensating Shaft Seal

Fluidtight sealing between a shaft subject to angular misalignment, or endplay during operation, and its housing is accomplished with a U-shaped molded rubber ring. One side of the U-shaped ring engages the shaft surface and is held in place by a garter spring. The other side is anchored to the housing. Rigidity of the sealing member is maintained by a metal ring partially imbedded in the rubber. In operation, the sides of the seal act as diaphragms and flex to accommodate angular movements of the rotating shaft. This flexibility characteristic also serves to compensate for axial sliding motion or endplay of the shaft. *Patent* 2,698,194 *assigned to Allis-Chalmers Mfg. Co. by G. D. Becker.*



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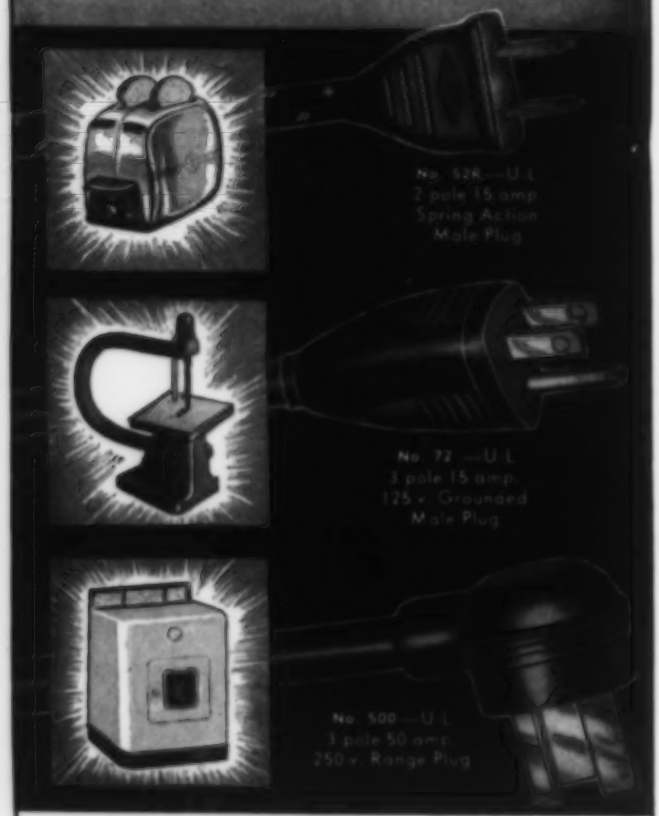

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New Machines

Metalworking

Riveters: Multiple-head rivet-setting machines feed and set up to 12 rivets at a time, in the same or different planes. The riveters consist of several individual basic machines, each mounted on a base and equipped for air operation. Components to be fastened are put in a work-holding fixture by the operator. Rivets are automatically fed and simultaneously set in each cycle. By changing the feeding parts, up to 12 rivets of different specifications can be set at one time. *Tubular Rivet and Stud Co., Wollaston, Mass.*

Press Brake: Press type brake of 150 tons capacity for piercing, blanking and shallow draw work on large sheet panels has bed and ram areas 40 in. wide and 15 ft 8 in. long. Without die sets, the machine weighs 35 tons and is equipped with three air counterbalance cylinders. Stroke is 5 in. and shut height between platens is 14 in. *Cyril Bath Co., Solon, O.*

Surface Grinder: Hydraulic feed surface grinder has 8 x 24 in. table with capacity of 12 in. under a full 10 in. diameter wheel. One-piece column and base construction assures permanence of alignment between vertical headways and cross-travel ways. Head of the machine has a grease-sealed ball bearing spindle carried on protected preloaded ball-bearing ways for ease of vertical movement. Hydraulic pump and control valve provide an infinite number of longitudinal table speeds ranging from 3 in. to 125 fpm. Hydraulic cross feed is variable up to a maximum of $\frac{3}{8}$-in. per table reversal. *Gallmeyer & Livingston Co., Grand Rapids, Mich.*

Drilling Machines: Royal Model LE 18 in. drilling machines are designed for production, toolroom, maintenance, and general purpose duty. Single-spindle floor models and single and multiple-spindle production bench models are available. Rated at 1 in. capacity in cast iron with a 1 hp motor, the machines are equipped with a No. 2 Morse taper spindle. A No. 3 Morse taper spindle is optional. A V-belt drive transmits motor power efficiently and directly to the 6-splined spindle, providing full torque at all spindle speeds. The spindle is full-floating on four precision, sealed, lifetime lubricated bearings. Six spindle speeds range from 390 to 3100 rpm with an 1800 rpm motor; 324 to 2580 rpm with a 1500 rpm motor; 259 to 2060 rpm with a 1200 rpm motor; or 216 to 1715 rpm with a 1000 rpm motor. Spindle speed changes are made through a tilting motor bracket which maintains uniform belt tension. *Cincinnati Lathe and Tool Co., Cincinnati, O.*

Tube Cut-Off Machines: Utilizing a shear type cut, two new Grieder machines cut off tubing of all sizes and shapes from $\frac{1}{4}$ to 4 in. OD. Model 2000 MAC

(Advertisement)

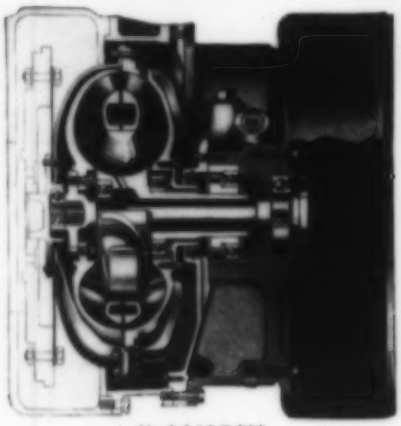
Fuller announces 3 new torque converter couplings

. . . designed for a wide variety of industrial applications

Three new Fuller Torque Converter Couplings nominally rated at 280 foot pounds of torque are now available for increasing work capacity in a wide variety of industrial applications.

The Fuller Industrial Torque Converter Couplings consist of three simple elements; impeller or pump, runner, and reaction member. With single stage two phase design, the reaction member is mounted on an overrunning clutch which permits rotation with the runner, and operation as a straight hydraulic coupling for high efficiency. The change from 2.1:1 conversion stage operation to straight hydraulic coupling stage and back is automatic, depending only upon the amount of torque required in the drive line.

Advantages of the 2.1:1 torque multiplication and smooth fluid coupling operation provided by the new Fuller Torque Converter Couplings include obtaining faster work cycles . . . with less downtime and less maintenance. Typical applications are: fork lift trucks, winches, loaders, self propelled cranes, truck cranes, lumber carriers . . . and diesel and gasoline locomotives.



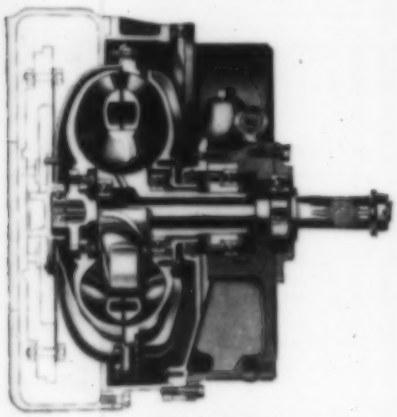
Model 12-T-280

The New 12-T-280

This new Fuller Torque Converter Coupling incorporates an SAE No. 3 clutch housing behind the converter. The output shaft is flanged for attachment of a single plate clutch flywheel.

The New 12-U-280

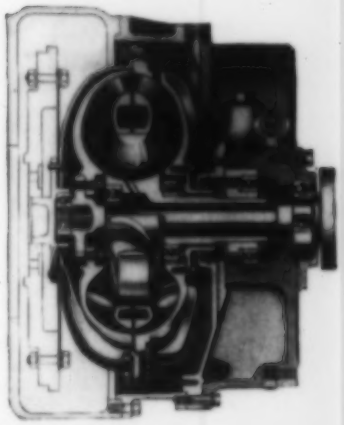
The Model 12-U-280 Fuller Torque Converter Coupling incorporates a 1½" ten-spline shaft on the output end, without clutch housing, for straight line drives through a universal joint.



Model 12-U-280

The New 12-H-280

A new model which incorporates a flange at the output shaft, for attachment of industrial type couplings.



Model 12-H-280

For Tough Tasks— It's Fuller by Far!

Where frequent start-and-stops, or heavy, intermittent shock loads threaten to overwork engines, transmissions, axles, brakes and tires . . . use the fluid cushioning of these new Fuller Torque Converter Couplings to *absorb* and *eliminate* shock loads.

Torque demand is matched to the load through the 2.1:1 torque multiplication of the converter . . . automatically changing to fluid coupling as the load is reduced. These new Fuller Torque Converter Couplings *keep* engines operating in the high rpm range under all conditions of vehicle load and speed.

See your equipment dealer *today*. Specify Fuller Torque Converter Couplings in your new equipment for better performance.

FULLER MANUFACTURING COMPANY
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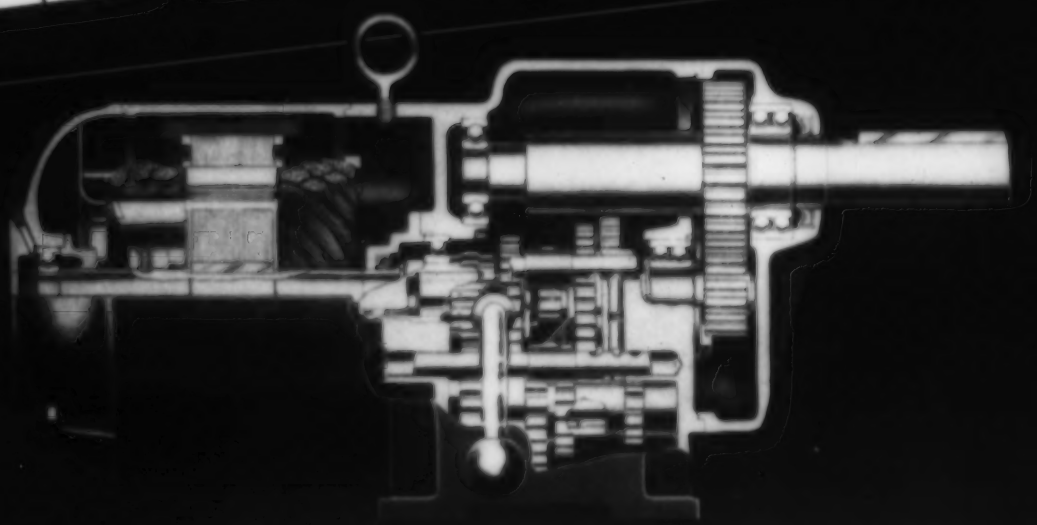

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cuts tubing ranging in diameter from ¼ to 2 in. with wall thicknesses up to 0.125-in. It makes up to 100 cuts per minute. Rate of feed is 600 fpm. Model 4000 MAC cuts tubing ranging in diameter from 2 to 4 in. with wall thicknesses up to 0.187-in. Opposed feed rolls automatically feed the tubing through the machine to a positive stop located in alignment with the stock. A horizontal blade removes the top portion of the tube, leaving an opening into the bore, then a vertical blade completes the cut without distortion and with minimum burr. Cutting is accomplished in ⅓-second on all wall thicknesses up to $\frac{1}{16}$-in. Lengths can be held to ±0.002-in. on light wall tubing. *Grieder Industries Inc., Bowling Green, O.*

Drill and Tapper: Model No. 410 machine locates and holds rivets or other headed parts for axial tapping or drilling. Automatic reversing attachments are used for tapping. Changeover from drilling to tapping takes about 10 minutes. The machine operates by electrically controlled compressed air on at least 50 psi air line pressure at approximately 500 strokes per cu ft of free air. Solenoid three-way valves controlled by relays and sensitive switches regulate the cycling. If a part is not properly positioned or the hopper is empty the machine shuts off. The machine is adaptable to hollow milling, centering, step drilling, countersinking, spot facing, reaming and certain combinations of these operations. *Batchelder Engineering Co. Inc., Springfield, Vt.*

Tube Bender: Automatic machine simultaneously forms two 180-deg hairpin bends in ferrous or nonferrous, finned or plain tubing. Cycle time is less than 3 seconds. Insertion of the tubing into the machine initiates the automatic cycle in which the tubing is bent and ejected after bending. Base of the machine houses electrical controls and a built-in hydraulic pump, motor and tank unit. The bending table on the end of the machine is powered by a hydraulic actuator. A radius bender block and a clamp block are mounted on this table, and a wiping block is mounted on the base in contact with the bender block. This arrangement makes possible the bending of light-wall tubing on small radii without flattening or lengthening and without the use of ball mandrels. Machine has a single-tube capacity of up to 1-in. diameter ferrous or nonferrous finned or plain tubing. Center-to-center bend radius is proportional to the tube diameter and wall thickness. Bends having legs up to 4 ft long can be handled. *Walter P. Hill Inc., Detroit, Mich.*

Deburring-Chamfering Machine: Model BMI-15 Burr-Master deburrs and chamfers internal splines, straight-sided or involute-form helical and spur gears ranging in size from 2 to 20-in. pitch diameter with a maximum of 4 diametral pitch. Throat clearance permits handling parts up to 22 in. OD. A spline driver is used for gears up to 6-in. pitch diameter; a drive gear is used for larger sizes. The machine chamfers both sides of the tooth and the root simul-

(*Continued on Page* 358)

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won't
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New, self-locking threaded Inserts and Tapped Holes.

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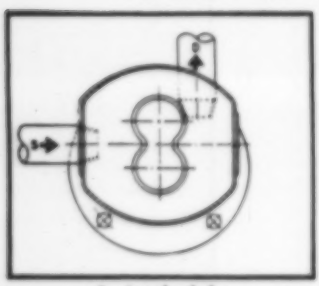
New MONOBLOC lets you hook up

WORTHINGTON MONOBLOC PUMP

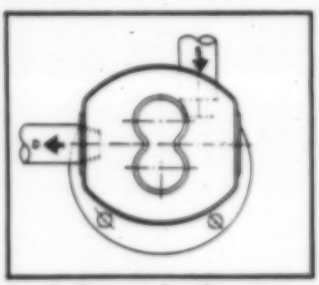
type GAFT, features rotary pump and close-coupled motor. It's just like the famous Worthington Monobloc centrifugal pump line except that coupling allows easy pump removal.

How you can use dual intake and discharge openings

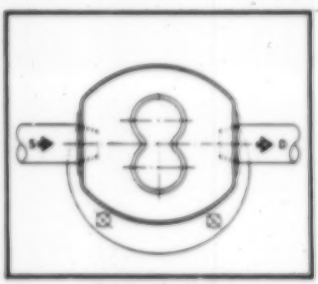
HERE ARE EIGHT OF THE 28 POSSIBLE ARRANGEMENTS:



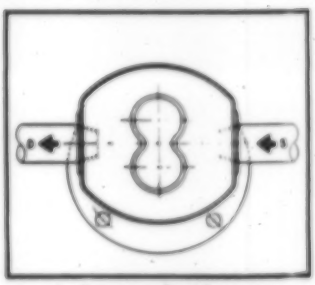
1. Intake left. Discharge top right.



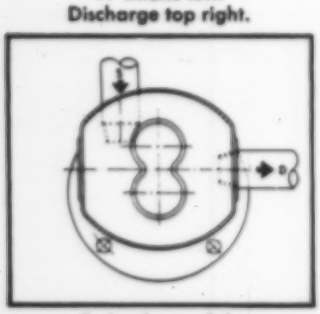
2. Same as 1 with pump direction reversed.



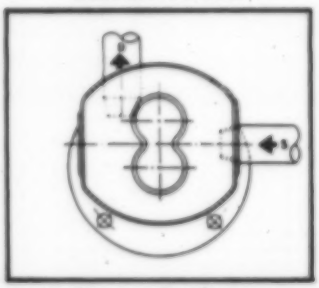
3. Intake left. Discharge right.



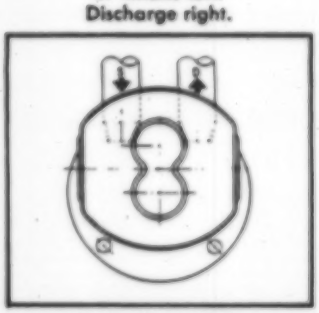
4. Same as 3 with pump direction reversed.



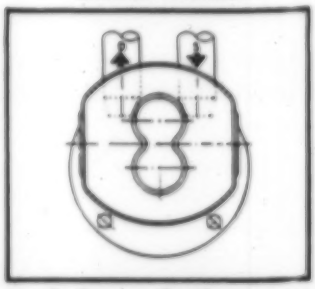
5. Intake top left. Discharge right.



6. Same as 5 with pump direction reversed.



7. Intake top left. Discharge top right.



8. Same as 7 with pump direction reversed.

rotary pump piping 28 ways!

This new Worthington Monobloc rotary pump is easy to design into compact new equipment or to adapt to existing layouts.

Dual suction and discharge openings, reversible pump direction, and four pump flange positions on motor add up to 28 possible arrangements to simplify pipe layout.

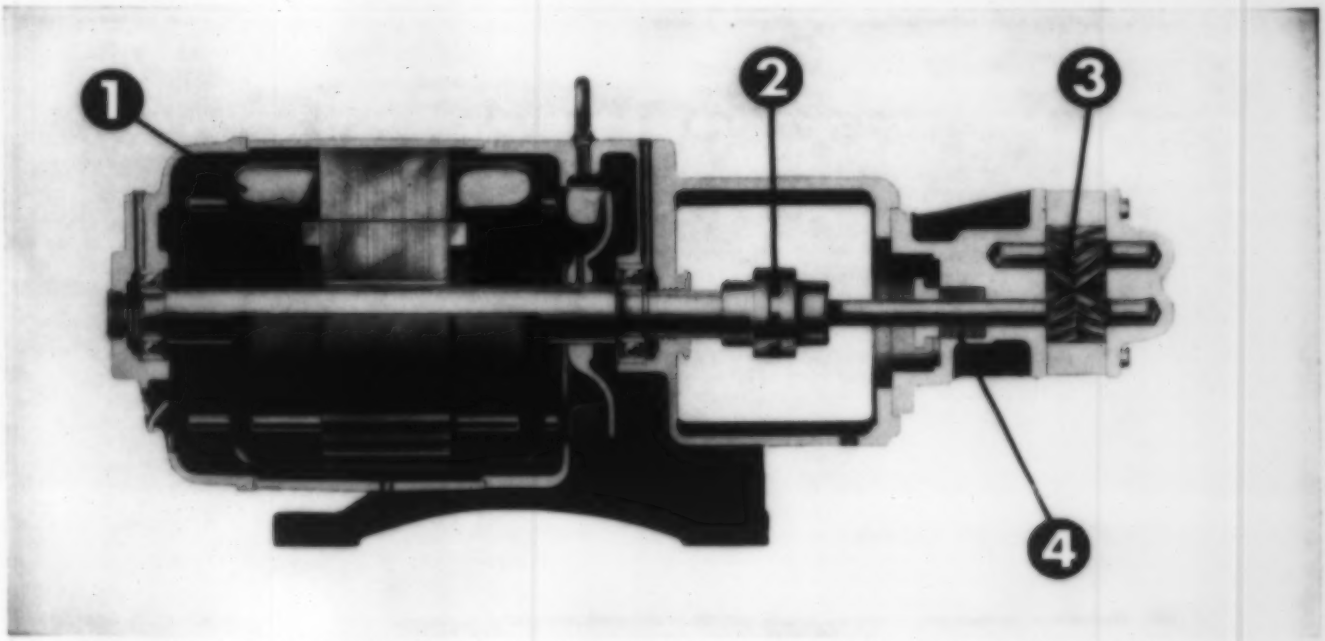
The Monobloc motor, on the new rotary, effects the same savings it has marked up for years on Worthington Monobloc centrifugal pumps. Fewer parts mean a more compact overall assembly that's easier to manufacture so it costs you less than separate pump, motor, coupling, and baseplate.

Standardization of pump and motor flange diameters and shaft lengths permit any pump to be mounted on any Monobloc motor.

There are no alignment problems with the Monobloc. Pump and motor are automatically aligned — eliminating end-thrust, binding, pipe strains, and resulting pump wear.

It's easy to service, too. A shaft coupling on the Monobloc rotary allows pump removal without disturbing the motor.

Get the whole story on the new Monobloc rotary pumps, type GAFT. Write today for bulletin W-484-S1. It gives complete data on features and applications. Worthington Corporation, Section PC.5.21, Harrison, New Jersey. PC.5.21



CUTAWAY VIEW OF GAFT PUMP. Available in four sizes, from 2 to 27 gpm at heads up to *150 psi*. Note Monobloc motor (1) available at 1800, 1200, 900 rpm, for all commonly used voltages, phases, and frequencies; motor-pump coupling (2) that allows quick pump removal; all-iron herringbone gear pump (3); packed stuffing box (4); a mechanical seal and/or relief valve are optional standard features.

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Compressors • Pumps • Multi-V-Drives • Allspeed Drives

NEW CUTLER-HAMMER 10250

STANDARD DUTY PUSHBUTTON STATIONS

3 element type... with indicating light

Bulletin 10250H1939 steel panel mounting "start-stop" with indicating light.

Same with padlocking feature on stop button to prevent operation.

Check the features. No other standard duty pushbutton station offers so much. U-shape wrap-around cover and frame make unit strong, serviceable yet light and small. Recessed pushbuttons prevent accidental operation. Optionally, the stop button can be padlocked against unauthorized use. Indicating light normally removed from front of case, but a simple change locks it in against pilfering. The same one low watt glow lamp serves both 110V or 220V, by changing one terminal connection. Plainly marked circuit arrangements facilitate correct hook-up. Removing cover places terminals out in open for maximum accessibility. Packaged connectors included, electrician does not have to make them up. Oversize insulation panel affords complete protection yet cut on bias for access to mounting screw-holes. Frame and cover finished inside and out in baked light gray enamel. Standard enclosure for surface mounting or steel front panel for cavity mounting. See your authorized Cutler-Hammer Distributor today and *see the difference*. CUTLER-HAMMER, Inc., 1310 St. Paul Avenue, Milwaukee 1, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ontario.

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CUTLER-HAMMER
MOTOR CONTROL
C-H

New Machines

(*Continued from Page 355*)

taneously, at the rate of 5 teeth per second. Depth of cutting stroke is infinitely variable. A circular form tool with three or four cutting edges is used for deburring and chamfering. Since the tool is positively positioned against a stop, it need not be adjusted after it has been rotated. Overall height of the machine is 80 in.; work height is 38 in. *Modern Industrial Engineering Co., Detroit, Mich.*

Welders: Line of engine-driven generator type welders is available in current ranges of 30 to 350 amp, ac or dc. One dc model is a dual purpose unit which handles all types of dc welding and can also be converted into an ac power plant by means of a switch. The ac model also has a 110-v dc outlet for operating universal drills and lights. Another model is equipped with high frequency so that it can be used for Heliarc inert gas welding. All the welders have infinite current adjustment steps. They are powered by air-cooled, four-cylinder, 20-hp engines. *Westinghouse Electric Corp., Pittsburgh, Pa.*

Plant Equipment

Oil Filter: Hydra-Filter filters contaminates down to ½-micron size from new and used hydraulic oil. It is also used for flushing hydraulic systems, for the transfer and handling of hydraulic oil directly from drums and for testing hydraulic systems. Filter is supplied with gear pump, electric motor, control panel with necessary gages, flow meter, reservoir and connecting lines. The reservoir and all piping are corrosion resistant. *Farnham Mfg. Div., Wiesner-Rapp Co. Inc., Buffalo, N. Y.*

Heat Exchanger: Panel Casing Aero heat exchanger conserves water in industrial cooling and provides temperature control within 2 F. It cools by evaporation and controls temperature by modulating the use of outdoor air. Four sizes offer capacities from 7,000,000 to 18,000,000 Btu/hr under standard conditions. *Niagara Blower Co., New York, N. Y.*

Power Plant Equipment

Air Compressor: High capacity piston type air compressor delivers oil-free air. All units are constructed for continuous operation while delivering up to 175 psi pressure. Specially constructed graphite or carbon piston rings eliminate the use of oil for lubricating cylinder walls. The compressor is suitable for all types of pneumatic tools and control systems. Compressors are rated for continuous operation at 35, 75 and 175 psi and from ¼ to ¾-hp. *Bell & Gossett Co., Morton Grove, Ill.*

Oil-Hydraulic Power Units: Series T-8 oil-hydraulic pipeless power package consists of an electric drive motor, oil-hydraulic pump and a control circuit mounted on an 8-gal reservoir. The units conform to JIC specifications and meet NEMA frame size specifications. Three pump capacities are available: 2.2, 3.7 and 5.2 gpm rated deliveries at 1800 rpm and zero pressure. Three electric drive motors, rated 1,

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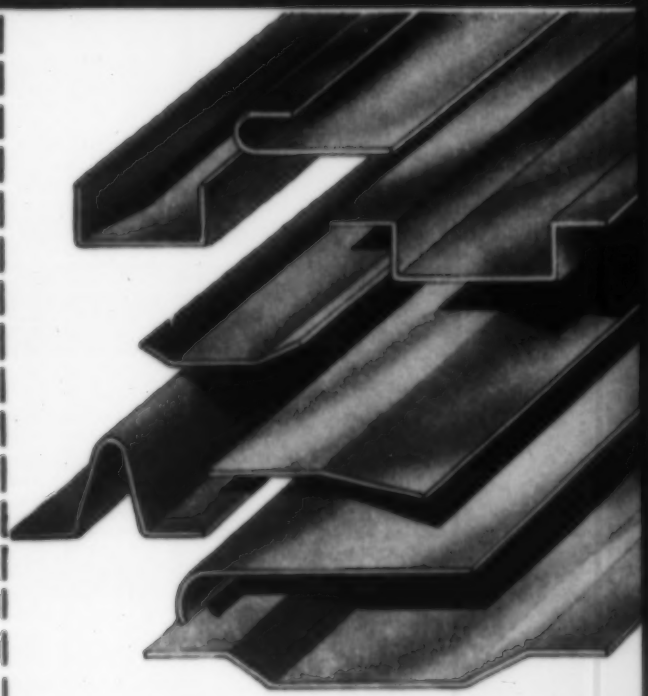

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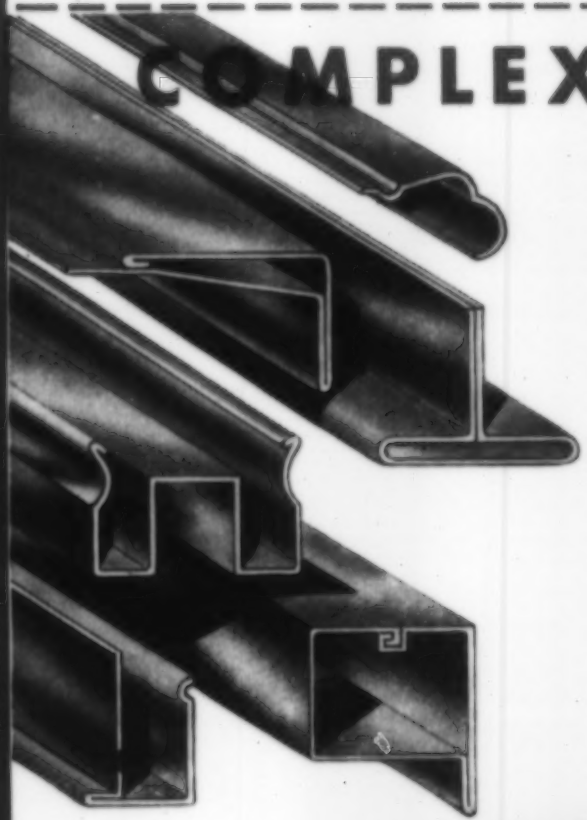

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